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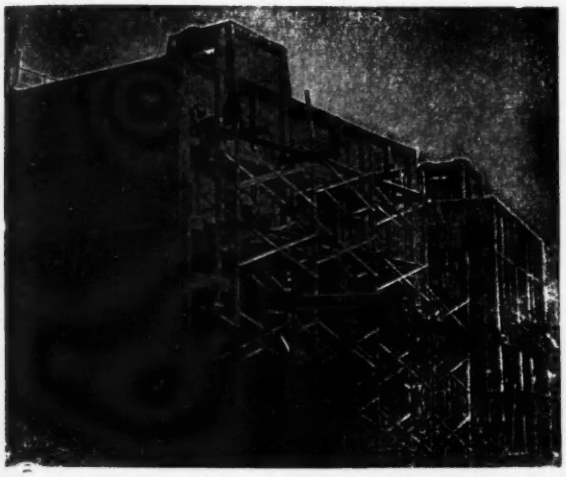

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Gas Journal

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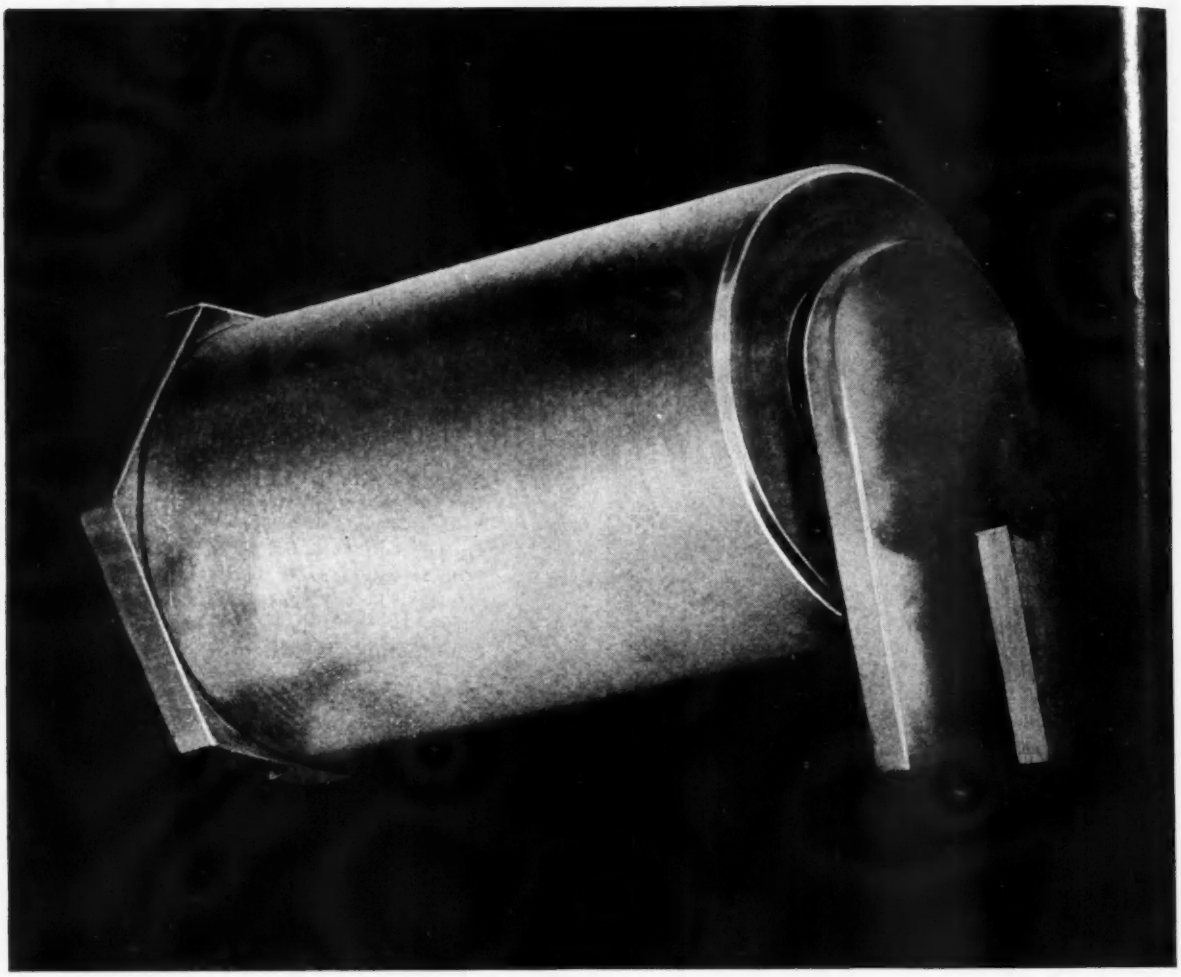

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Gas Journal

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Underground storage on the Continent

WITH the increasing interest being taken in the storage of large quantities of gas underground, it seems reasonable to suppose that any progress in the development of this particular branch of the industry on the Continent should supply information of direct use to gas engineers in this country. We are therefore publishing this week the first part of a report of a working party on gas problems set up by the United Nations Economic Commission to Europe.

The Continent with its greater distances to cover and its smaller average density of population, has problems to face that may be slightly different to those of our own gas industry. It is only since the war, however, that the great increase in long distance supply systems feeding into municipal networks in a country such as Western Germany, has resulted in the need for the storage of large quantities of gas in order to make more flexible the traditionally inflexible system of buying gas under contract from coke oven plants, owned and worked by other industries, whose economic demands have little or nothing to do with the gas industry.

In France, too, the discovery of the source of natural gas at Lacq has opened up possibilities of transmitting large quantities of gas to places where before it had not been used to any extent. This source should make possible industrial development in parts of France which had hitherto been retarded by a shortage of cheap fuel and energy. But there are likely to be large-scale storage problems.

Underground gas storage is in fact no new thing, since it has been developed in America since the war. But the Americans had the great advantage of possessing exhausted natural gas wells near the points of gas consumption, into which gas flowing through the long transmission lines from the Texas oilfields could be stored until needed. In this way the load factor on the transmission mains could be kept as high as possible throughout the year and with an increase in winter consumption by the sharp rise in domestic sales, supplies could be easily maintained.

In Europe, however, with a very few exceptions, such a means of underground storage did not exist. A completely different system was needed and it was because of this that the 'aquifier' was developed.

In this method of storage, use is made of the fact that in certain geological formations containing sand and water, the water may be placed by gas with an increase in hydrostatic pressure. After pioneering work in America and the solution of the preliminary problems facing any new enterprise of this sort, several of these aquifiers are beginning to appear on the Continent and are successfully storing large quantities of gas.

Having solved the purely technical problems involved and discovered the right type of anticlinal formation in which these underground structures may be found, what are the main advantages to the industry? And if these are substantial, how can we in Britain profit by them?

The placing of these underground storage systems in relation to the points of gas production and consumption is most important. The report deals in detail with three main systems, examples of all of which are to be found on the Continent. The storage may be part of a closely integrated system, such as the gas supply system of the city of Hamburg; it may be at the end of a long transmission main; or near the production point.

So important is the relative position of the storage system that this may well constitute the difference between there being an economic return on the capital investment or not. In the first case, the underground storage system is a means of keeping production plant running as far as possible on base load throughout the year and thus using auxiliary gas-making plant as little as possible, except at times of maximum demand at the coldest periods of the winter. In this way a gas undertaking may also take large volumes of gas bought outside the industry under contract. Excessive volumes of gas can be stored during the summer, and when autumn comes an increasingly large proportion of gas received can be distributed, progressively supplemented by gas from storage.

The aquifier at Beynes, near Paris, is an example of the second storage position, since it receives gas from

the coke ovens of the Lorraine steelworks and stores it for distribution in Paris. Since gas consumption in Paris at present is equivalent to about half that for the whole of France, the placing of the storage at this point is most suitable. A second aquifier is being built at Vernon, also in the neighbourhood of Paris to take natural gas from Lacq. Individual aquifiers, the report points out, due to physical differences in the formations, possess their own properties of quick filling and quick emptying. The Vernon aquifier, though much bigger, cannot supply gas at such a great rate as does its counterpart at Beynes.

The aquifier at Lussagnet, near Lacq itself, is an example of the third position. Here due to the need for processing the crude natural gas, it is necessary to carry a substantial stock of purified gas ready for distribution. This the aquifier does and makes it possible to work a purifying plant of economic size at a continuously high load factor.

How is such a system of large-scale gas storage applicable to Great Britain, and what steps are we taking to provide ourselves with the necessary equipment?

The particular organisation of the gas industry in this country, whereby it is largely responsible for its own gas manufacture, together with an almost complete lack of any natural gas deposits, have favoured the type of grid system developed since the war. On balance some storage capacity became superfluous because good communications and improved instrumentation showed where demands were greatest, and plant was available for transporting gas to these points. With increased costs of coal and freight charges, the tendency to buy more coke oven gas and refinery products has caused engineers to look for means of gas production even further away from points of consumption. Developments in the gasification of low grade coals at collieries and the importation of liquid methane and its storage on the coast are likely to change the shape of the British gas industry in the future. The new processes of oil and coal hydrogenation will produce very large quantities of gas in comparatively small plants, which if connected to a national grid, will contribute to gas production throughout the country. Just as at Beynes gas from Lorraine is stored for Paris, so gas made in the Midlands coalfield might be stored in the south of England for the south coast resorts.

So far the only progress made in providing underground gasification in Great Britain, other than the natural gas well at Cousland, near Edinburgh is the cavity in the salt measures at Billingham, capable of storing a mere 100 mill. cu.ft. We have every reason to suppose, however, that the surveys to be carried out in suitable geological strata in the south of England will be successful in finding a possible site for an aquifier.

Until this particular problem of really large storage is solved, it is quite clear, we think, that difficulties of providing costly peak load gas are likely to face the industry for some time. Without it, no system of centralised gas production embracing a national grid, is likely to be financially successful.

Kitchen planning contest

LAST week we attempted to stress the importance of the Hotel and Catering Exhibition (which opened yesterday) to an industry such as ours. This week we are pleased to be able to report the successful conclusion of an enterprise designed to forge still more strongly the link between the gas industry and the catering colleges, and which also has a bearing on Hotelympia.

Last Thursday Sir Henry Jones, M.B.E., the Chairman of the Gas Council, presented prizes to the winners of the first gas industry-sponsored Plan-a-Kitchen Competition in which full-time and part-time catering students were invited to submit plans for a kitchen serving 250 to 300 lunches and/or dinners a day. For a first effort the response, from 68 colleges in England Scotland and Wales, was gratifying. Next time—the competition is to be repeated two years hence—probably many more young people will compete.

The first prize of £50 was won by Gillian M. Grant of Torquay, the second prize (£30) by Clive Armitage, of Bodmin, and the third prize by Theta Tuffin, of London; other special prizes were also presented.

The judges comprised Madame S. B. Prunier, the well-known London restaurateur, Mr. H. R. Duffield-Harding, Chief Officer of the L.C.C.'s School Meals and Catering Department, and Mr. P. H. Venning, Comptroller of Supply to the Royal Household.

Although perhaps less spectacular than some of the competitions organised by the Gas Council in the past, this one seems to us to have a value very much greater than its size. In the first place it does, as we have said, strengthen the link between the gas industry and the catering colleges, but it also shows by implication that gas is synonymous with good kitchen design. It reveals the gas industry as one concerned with raising the standards of catering, and by exhibiting the successful plans on the Gas Council stand at Hotelympia an important and effective attraction is added to the existing display.

When the prizes were presented Madame Prunier made particular reference to the high standard of the plans submitted, and this was no testament given out of politeness. The standard was indeed high, and the Gas Council can feel gratified by its association with entries of such a calibre. Incidentally, we noticed that at the conclusion of Sir Henry's speech he slipped in a reference to the 'exciting times' through which the gas industry is passing, and mentioned the major technical developments being undertaken, plans aimed primarily at reducing the price of gas and enabling us to give our customers a first-class service at a lower cost.' This was the first time we have heard Sir Henry speak in public since he became Chairman, and we wonder whether this dash of salesmanship is an example of the way in which he intends to publicise the aims and virtues of the industry. We hope so. The industry's premier task at the present time is to sell gas, and there is nothing like a good example being set at the top.

Commentary on the News

New look at the Building Centre

WE happen to number ourselves among those who regard the gas section at London's Building Centre as having an importance consistent with the (no doubt very substantial) rent charged for this much sought-after floor space. Its real value can never be assessed for the results of its efforts are felt in the business of area gas boards all over the country, but its influence on architect, builder and customer is very considerable.

For this reason we note with pleasure the fact that the section is in process of having a face-lift. It is long overdue. The existing decor was adopted as long ago as 1952, although bits and pieces have been modified from time to time. All things considered it has lasted extremely well, but there can be no denying that since the rival section next door was refurbished in 1957 gas has been outshone—literally—by electricity.

This is particularly true of the entrance to the section which looms as a dark cavern beside its brilliantly lit neighbour; small wonder that visitors often mistake it for an extension of the E.D.A. display. Heaven forbid that the two industries should indulge in a battle of candle-power, but something very compelling must be done even to secure equality. Equally, we hope the Gas Council will not indulge in anything as blatant as the neon sign 'Electricity' which hangs in a window and directs its message at passers-by, but a little ingenuity should permit the entrance of the gas section to be clearly seen from without.

A start has been made on what will be a major display of central heating and warm air equipment, and we understand that further plans include the provision of a stunning model kitchen. We look forward to the new section with considerable interest; it should be completed by mid-1960. In the meantime it must be recorded that whatever the dust and dirt resulting from the work being undertaken, the remaining exhibits appear miraculously preserved in their usual spotless elegance.

Russian coking technology

NO thinking person today can fail to recognise the growing attention we must pay to technical development in the U.S.S.R., and it is good to learn of a new service which will provide translations of material likely to interest engineers in our own sphere.

As some readers probably know, the Department of Scientific and Industrial Research has inaugurated, and is supporting, a scheme by which cover-to-cover translations of Russian technical journals are made available. As part of this scheme, an English version of *Koks i Khimiya*, under the title *Coke and Chemistry, U.S.S.R.*, is being produced by the Coal Tar Research Association in conjunction with the expanding British Coke Research Association.

This Russian journal is an important one for engineers, chemists and all technical staff interested in the production of metallurgical and gas coke and the recovery and refining of by-products. Of especial value will be the information given on current advances in Russian coking technology. The first issue to be prepared is that for August, 1959, and specimen copies are now available on request from the Coal Tar Research Association, Oxford Road, Gomersal, Leeds.

Nothing stuffy about gas

ADVERTISING has developed in some interesting ways during recent years, some of them based on the realisation that teenagers constitute a significant part of the purchasing public. Gramophone records are an obvious example of the type of goods for which teenagers somehow find huge sums of money, but the advertising man's skill really comes into play when he convinces the youngsters that some commodity which they have always regarded with contempt—cocoa, for example—is really the fashionable thing to have.

Allied to this is the recognition of the fact that adult buying habits can be formed during childhood and adolescence. In the gas industry the old cry that the schoolgirls of today are the housewives of tomorrow has long been heard, but the moral was interpreted as being liaison with schools, leading to lectures, visits to the works and showrooms, etc. We certainly do not dispute the value of such activities, but the fact must be faced that they are associated in the child's mind with the rest of the educational pursuits forced upon him or her. Much subtler, and probably more effective, are the methods employed to interest and influence youngsters in ways far removed from the schoolroom. The fabulously successful Chris and Carol strip in *Girl* is an outstanding example of how this can be done.

On somewhat similar lines is an eight-page supplement to be included in the *Express Weekly* issue of the week ending January 23. Prepared by the Publicity Department of the Gas Council, this is designed to show gas as an exciting and progressive fuel, in which laudable object it is highly successful. 'The Story of Mr. Therm' traces the history of the industry through a selection of colourful episodes, 'The Great Experiment' describes the adventurous first voyage of the Methane Pioneer, and other attractions include features on the uses of gas in industry, the mysteries of Watson House, how a gasworks functions and the by-product story; to cap it all there is a competition based on the relative value of the various services gas provides. It is all very well done, and we hope to see further examples of this kind of publicity, a kind which shows that even if great grandma used it, there is nothing stuffy about gas.

Well, someone spoke for gas

OUR recent plaint entitled 'Who speaks for gas?' seems to have aroused a fair measure of agreement. Clearly a great many people in the industry would like to counteract anti-gas correspondence in our newspapers, but they all feel it is up to the Gas Council to act as official spokesman. However, we were pleased to note that at least one person was not content to wait for the powers that be to find their voices. When the *Evening News* published (on January 5) an article by Richard Raine maintaining that 'Oil will keep the home fires burning,' a spirited denial came from Mr. C. A. Lewis who pointed out that there is an abundance of very efficient gas heating appliances well able to keep the whole house warm at very reasonable cost.

Mr. Lewis, whose name was long associated with Radiant Heating Ltd., and is now Sales Manager of Standard Sales Ltd., has broken the ice; we hope many others will now take the trouble to stick up for the industry in which they profess to believe.

FROM A UNITED NATIONS E.C.E. WORKING PARTY REPORT

THE QUESTION OF UNDERGROUND GAS STORAGE IN EUROPE

1.—Technical possibilities

THE *ad hoc* working party of the United Nations Economic Commission for Europe on gas problems, after considering at its fourth session problems of improving the flexibility of gas porduction, decided to make a more thorough study of the question of underground storage.

The gas industry is in fact faced with a most difficult dilemma. On the one hand, there are the consumers' needs, which are variable and, if they are to be properly satisfied, call for extreme flexibility in supply; on the other hand, there are the economics of production and long-distance transmission, which require the greatest possible regularity if reasonable cost levels are to be maintained.

It is recognised, without prejudice to other possible solutions, that, where practicable, underground storage should offer a particularly attractive way out of this dilemma.

In the United States of America, underground storage has been practiced for many years as a means of maintaining an even flow in natural gas transmission lines. The gas is usually injected into old depleted wells situated near the pipe-lines. In a few very rare cases, this is also done in Europe, for example, at Vaux-en-Bugey in France and some old wells in Poland, Rumania and the U.S.S.R., but there the number of old gas wells fulfilling the required conditions is insufficient and it has been necessary to turn to other methods, mainly that involving the use of aquiferous formations. This is the method which must inevitably be the one chiefly used in Europe. It is the one that has attracted most attention.

An underground reservoir of the kind referred to is formed by an aquiferous structure generally consisting of sand, or, in other words, of small grains of silica separated by tiny spaces. These spaces are normally occupied by water which, except for a certain quantity called interstitial water, can be removed and replaced by gas. This layer must naturally be covered by an impermeable layer capable of holding back the gas.[1]

Natural characteristics

Such an aquiferous structure possesses certain natural characteristics which have important economic implications. These are:

1. *Porosity* is the ratio of the volume of the spaces to the total volume of the sand expressed as a percentage. This makes it possible to measure the volume available for gas storage, after deduction of the volume represented by the irreducible interstitial water.

2. *Permeability* is the ease with which fluids move through the sand; it helps to indicate the speed at which gas can be injected into, or withdrawn from, a particular formation, and is expressed in darcys.

3. *The rate of flow* of the underground water affects the pressure balance between the liquid and gaseous phases. The combination of the last two characteristics constitute the water-drive, which governs pressure balancing phenomena associated with changes in the volume of gas stored.

4. *The closure* is the vertical distance between the highest point of the dome and a horizontal place projected from the relatively highest leakage line—with a safety margin of 7 to 10 m. This affects the available volume.

5. *The tightness of the overburden,* or impermeable layer, is decisive both for the possibility of storing at all and for the danger of pollution of the water above.

6. *The chemical composition* of the porous medium is important since it might lead to certain undesirable reactions.

Finally, there is the *cushion gas,* the volume of which depends, partly on the shape of the roof of the reservoir and the varying permeability of the layers next to the roof —this part, called 'lost gas' or 'trapped gas,' is irrecoverable—and partly on the final unit rate of withdrawal adopted for the wells—this part, or the cushion gas proper, may be withdrawn at the end of storage operations.

These natural conditions are bound to have a considerable bearing on the cost of operation of every existing or prospective storage reservoir.

Several reservoirs

There are several underground storage reservoirs now in use in Western Europe, they are:

1. *The Reitbrook storage reservoir, near Hamburg.* This formation consists of a reservoir rock in extremely fine sand situated at a depth of between 260 and 330 m. (850 and 1,080 ft.). Its physical characteristics are: Thickness of structure used for storage, 15 m. (49 ft.); net porosity, 21%; thickness of clay overburden, approximately 60 m. (197 ft.); gas pressure after injection, 35 atmospheres; total number of wells, 17, of which six are used for gas injection and withdrawal.

2. *The Beynes storage reservoir, near Paris,* is formed by a rather flat aquiferous structure situated 35 km. (22 miles) from Paris at a depth of more than 400 m. (1,312 ft.). This is an anticlinal layer covered by an impermeable layer of clay 7 to 8 m. (23 to 26 ft.) thick. The Wealden (lower cretaceous) sand layer is 30 to 35 m. (98 to 115 ft.) thick. Net porosity varies from 24% to 33%, after allowance is made for the irreducible interstitial water, with excellent permeability of the order of 4 to 15 darcys. The hydro-

static pressure of the water in the Wealden layer is approximately 40 atmospheres. The project calls for seven control wells and 14 operating wells—eight of which have already been drilled[2].

3. *The Engelbostel storage reservoir, near Hanover,* consists of a horizontally curved anticlinal formation. The storage strata are of impermeable sandstone lying at a depth of 180 to 250 m. (590 to 820 ft.). The sandstone strata have a total thickness of 40 m. (131 ft.), of which 20 may be used for storage. The sandstone is fine and heterogeneous, with a porosity of 24% and a permeability of 300 millidarcys. The storage pressure is 35 atmospheres and the hydrostatic pressure of the gas about 30 atmospheres. There are 26 wells, of which 15 are operating wells and 11 are control wells.

4. *The Vernon storage reservoir 80 km. north-west of Paris.* This anticlinal formation, part of which extends under the River Seine, is situated at a depth of 385 to 450 m. (1,263 to 1,470 ft.). It is rather flat and consists of two layers of Upper Jurassic sand. The overburden is an impermeable layer 80 m. (262 ft.) thick. The formation is so heterogeneous that its porosity varies between an average of 10% for the sandstone rock and an average of 30% for the sand. Permeability ranges between 30 millidarcys and several darcys. Hydrostatic pressure at a depth of 400 m. (1,312 ft.) is approximately 53 atmospheres. The water is slightly saline (6 g. of NaCl per litre). The useful part of the formation is approximately 6 km. (3.7 miles) long and 2 km. (1¼ miles) wide.

5. *The Rostoki underground storage area in Poland* has been in operation for some time; it is an old depleted well situated in the natural gas region of southern Poland.

6. *The Lussagnet underground storage area in south-western France.* The reservoir layer is situated in an anticline of the Miocene level (tertiary era). Its average thickness is of the order of 40 m. (130 ft.). Its highest point lies at a depth of 545 m. (1,788 ft.), or, in relation to sea level, at −420 m. (1,378 ft.). The isobaths have an ellipsoidal tendency: Their main axis, somewhat concave towards the bottom, lies WNW/ESE; isobath −525 m. (1,722 ft.) is approximately 4 km. (2.5 miles) long and 2 km. (1¼ miles) wide. The reservoir consists of unsolidified sand of heterogeneous continental facies, containing slightly mineralized fresh water. The sand is of irregular granularity and has many marlaceous intercalations, probably lenticular, especially in the upper part. Pressure in the structure is 56 to 60 kg. per sq.cm. (54 to 58 atmospheres). Fifteen operating wells have been drilled so far. Ten of them are fully equipped and in operation. The present plan calls for 20 operating wells, plus two or three observation wells. These data are summarised in Table 1.

The physical characteristics referred to above, and others not mentioned, determine the gross and net capacity of a reservoir. Hourly withdrawal capacity also depends on the physical characteristics of the structure in which the gas is stored, and, in addition, on the economic conditions governing the operation of the reservoir to the extent that these conditions tend to increase or decrease the number of operating wells. It is at this point that technical and economic considerations confront each other.

Diversity of figures

The data in Table 1, most of which are still estimated figures, bring out one basic fact; the extreme diversity of the technological characteristics of the various storage reservoirs as regards both storage capacity and hourly rate of withdrawal. This fact alone should make one wary of comparing the cost of storage in each of the reservoirs examined in this study. Such wariness is doubly justified when the diversity of operating conditions, which is just as striking, is taken into consideration. The point is that an underground storage reservoir, while always having a regulatory function, exercises it within a particular gas system which dictates the way in which the reservoir will be used within the limits of its physical characteristics. Accordingly, the economics of a reservoir cannot be appraised in isolation but only in relation to the whole complex of which it is a part.

The location of an underground storage reservoir determines how it will be used; conversely, underground reservoirs are sought in regions where their use is most economic. The number of alternatives is fairly high since they are determined by numerous compromises between, on the one hand, geological and geographical possibilities and, on the other hand, the search for what would be best from the economic point of view. In Europe, the existing and projected reservoirs are found in three different locations, although there is no reason why a number of intermediate possibilities should not exist.

Three locations

1. The Reitbrook reservoir, in West Germany, serves an independent gas production-distribution system.

2. The Beynes and Vernon reservoirs, in France; the Engelbostel reservoir in West Germany; the Buguruslan reservoir and the projected reservoirs in the Leningrad and Moscow areas, in the U.S.S.R., are situated at the end of long-distance gas transmission lines.

3. Finally, two of the storage fields studied are found

TABLE 1
Basic technical and economic characteristics of the principal European underground storage reservoirs

Location of reservoir	Gross storage capacity (mill. of cu. m.) (*a*)	Volume of gas cushion (mill. of cu. m.) (*a*)	Net storage capacity (mill. of cu. m.) (*a*)	Permeability (in darcys)	Porosity (in %)	Max. hourly withdrawal capacity (in cu. m. per hour)
Beynes	320—350	140 to 150	140 to 200	4 to 15	24 to 33	250,000(*b*)
Engelbostel	200			·3	24	54,000(*d*)
Lussagnet	1,000(*c*)	500	500	·5 to 50	10 to 25	200,000
Reitbrook	100	25	60 to 75	—	21	65,000 to 104,000
Rostoki	30	12	18	·10 to ·06	12	7,000
Romania	—	—	66	—	—	41,600
Vernon	1,000	500	500	·3 to 3	10 to 30	160,000

(*a*) Measured at atmospheric pressure. (*b*) Maximum envisaged for 1961. (*c*) Might increase to 2,000 mill. cu. m. (*d*) Present rate 32,000 cu. m. per hour.
(*Note*—1 *mill. cu. m. are equivalent to* 35·3 *mill. cu. ft.*).

near the area of production and at the beginning of long transmission lines; they are the Lussagnet reservoir, in France; and the Rostoki reservoir, in Poland.

A glance at the gas supply map for Western Germany will show that Hamburg and its surrounding area lie outside the long-distance transmission system which starts from the Ruhr and extends over the greater part of the country. Underground storage was therefore envisaged not as a means of securing the optimum utilisation of an extended system of gas pipe-lines, but solely as a means of regularising the supply within an almost independent production-distribution system.

The whole of the available sources of gas for the town of Hamburg, consists of two gas coking plants, a coking plant belonging to a third party, a refinery from which gas is at present taken and a natural gas field situated fairly close to the urban area. Plans for the future include the use of a plant for the treatment of light petroleum distillate and perhaps also of imported liquified natural gas. The base-load gas is the coal gas produced by the coking plants, which have a total throughput capacity of 2,560 tons a day. All these coking plants together will supply about 1.1 mill. cu.m. per day of base load gas. In addition, there is at the present time an agreement with refineries, which supply 75 mill. cu.m. of gas a day, i.e., the equivalent of 110 mill. cu.m. of coal gas delivered regularly, winter and summer. Then there is the natural gas used, which represents the equivalent of 60,000 cu.m. per day of coal gas. The natural gas and the refinery gas have to be converted by cracking before they can be mixed with the coke oven gas.

These means of production are rather inelastic, either by nature (coke oven gas) or because of being subject to contract (refinery gas).

There were some fairly high winter peaks, and the problem was to meet these peak demands as fully and economically as possible, especially since a heavy increase in consumption for heating purposes was to be foreseen. It was a matter either of installing flexible production units to supplement the basic plant or of providing storage facilities over and above the distribution network gasholders, which have a total capacity of 500,000 cu.m.

Foregone conclusion

The existence among the above-mentioned gas supplies of large quantities of refinery gas with a high calorific value—6,500 kcal. per cu. m. as against 4,200 kcal. per cu. m. (for the distributed gas—685 and 443 B.t.u. per cu.ft. respectively)—made the economic value of the underground storage solution a foregone conclusion, since more calories could be stored for a given volume of gas. The plan for the utilisation of refinery gas then took the following form: During the summer, the refinery gas would be piped into storage; in winter, it would go straight from the refinery to the cracking plant, where it would be mixed with gas drawn from the underground storage field, of which the physical characteristics and the storage and withdrawal capacities have already been indicated. It will suffice here to recall that the normal storage capacity of 60 mill. cu. m. and the maximum capacity of 75 mill. cu. m. of refinery gas are equivalent to 94 and 116 mill. cu. m. of coal gas respectively. These figures represent approximately one-quarter of all the gas distributed annually and half the gas used in the domestic sector in the Hamburg undertaking, and exceed by from 33 to 66% the present consumption for heating, which amounts to 70 mill. cu. m., but do not cover the difference in consumption between the six winter months and the six summer months, which amounts to about 165 mill. cu. m.

In these circumstances, the gas supply system of the town of Hamburg can be organised as follows, with provision for a certain safety margin to cover the foreseeable increase in consumption. Coke oven gas will constitute the base-load gas, with a load factor of 92 to 95%. The refinery gas will be stored underground from April till the end of August. At the beginning of September, it will cease to be stored and will be used to cover the seasonal increase until the end of March. During the coldest time of the year, from December to the end of February, the refinery gas stored during the summer will cover the winter peak. This scheme thus constitutes a system with three distinct phases corresponding exactly to succeeding seasonal consumption requirements.

Peak demands

So far as concerns the peak demands themselves, they are of the order of 2.1 mill. cu. m. per day as compared with a mean winter consumption of the order of 1.8 mill. cu. m. per day, the difference of 300,000 cu. m. being broadly within the limits of the daily withdrawal capacity shown in Table 1.

Two reservoirs which can be considered in connection with an underground storage field situated at the end of a long-distance transmission system are the one at Beynes near Paris and the one at Engelbostel.

The Beynes underground storage field is in the immediate vicinity of Paris, at the end of the transmission line bringing gas from the Lorraine coke ovens to the Paris region.

The characteristics of the Paris area from the point of view of the gas market show that present consumption amounts to about half the total consumption of gas in France. The sendout modulation tends to increase from year to year. While at the present time the ratio between the monthly sendout averages for February and August is about 3, the ratio between the lowest daily sendout for August and the highest for February at a temperature of −10°C. in the middle of Paris is 6, and it is estimated that in three years it will be 8. To meet this situation, gas is supplied by the gas stations in the Paris system at a sendout rate of 6.8 mill. cu. m. per day, to which is added a continuous supply from the Lorraine steelworks and colliery coke ovens carried by the Gas de l'Est transmission lines.

This additional supply amounts to more than 1 mill. cu. m. per day in summer and 800,000 cu. m. per day during very cold spells in winter, the amount being smaller in winter because during that season more gas is taken by local distribution spurs between the east and Paris. Altogether, the total available supplies of gas for the Paris area amount, during a severe winter, to 7.6 mill. cu. m. Consumption increases, however, by about 220,000 cu. m. per degree of cold below 0°C. At a temperature of −10°C, this means a consumption of about 9.5 mill. cu. m. per day, or 2 mill. cu. m. per day more than can be provided by the normal means of supply. In other words, supplementary means of supply have to be brought into use as from 0°C.

It may be said that at the present time about 200 mill. cu. m. more gas at 4,600 kcal. per cu. m. (485 B.t.u. per cu.ft.) is consumed from October to March than during the summer period. This consumption is covered, partly by altering the load factor of the basic production units, and partly by using supplementary production units.

In view of the foreseeable increase in consumption during the coming years, it was necessary either to build new coking plants operating with a low load factor, or to install new peak-demand plant also operating with a poor load factor. These were the circumstances in which the storage field at Beynes was brought into use.

Table 1 indicates the chief technical features of the Beynes reservoir, *i.e.*, a large effective capacity and mean and maximum daily sendouts which should increase from year to year; from 1.2 mill. cu. m. in 1958-59 to 3 mill. cu. m. by 1960-61 and 1.6 mill. cu. m. to 6 mill. cu. m. respectively. If these figures are compared with those given in Table 1, it will be seen that the Beynes reservoir can easily cover the additional needs due to temperature variations. It is preferable, however, to put the reservoir to rather different use, partly because peak production facilities have already been installed. Thus, in order to minimise the cost, the tendency in practice is towards a system which will ensure that the plant is used as regularly as possible. For the winter season therefore the base load gas proper will come from gas producing coke ovens and Lorraine gas and gas to cover the average winter additional demand will be taken from underground storage. It will be recalled in this connection that the additional demand is of the order of 200 mill. cu. m. for the winter and that the effective storage capacity will amount to between 70 and 85% of this amount. For gas to cover sharp peaks of short duration, supplementary production facilities, and gasholders will be called into service.

Under present consumption conditions, the Beynes reservoir therefore seems well able to satisfy the seasonal needs of the Paris region. But the prospects are that in a few years it will rapidly become inadequate, and it is then that the Vernon storage field, which is much larger but has a lower hourly withdrawal capacity and is intended to receive natural gas, will probably begin to play its part.

Although it serves an area less densely populated than the Paris region, the Engelbostel underground storage field, near Hanover, is of approximately the same type as the Beynes reservoir. It was particularly advantageous to be able to use an underground storage field in the neighbourhood of Hanover because it is situated at the end of a gas transmission line from the Essen region about 250 km. (155 miles) in length, and is near a large consumption centre, which includes, besides the Hanover urban area, the urban development of Brunswich and is connected with Goslar and Kassel further to the south.

The function of this reservoir is mainly seasonal, but there are plans for using it on Sundays and holidays to take additional volumes of gas which will immediately be withdrawn from it on the following working days.

Natural gas field

The underground storage field at Buguruslan in the U.S.S.R. is not an artificial underground reservoir built into an aquiferous formation, but a reservoir in the depleted natural gas field at Boshotovsk. It is about 10 km. (6 miles) from the town of Buguruslan, which it is intended to serve. This reservoir is of purely local importance and it is in no way comparable to the big storage fields which it is intended to bring into use near Kiev, Leningrad, Kuibyshev and Kazan, where suitable formations have been identified.

The Lussagnet underground storage field is undoubtedly of a rather exceptional kind. In this case, the purpose is not to stabilize a production-distribution system, as at Hamburg-Reitbrook, or a transmission system, as at Beynes or Engelbostel, but to stabilise the flow of gas between a production centre, Lacq, and a large transmission network. The considerations which led to the use of the Lussagnet formation are very clearly described as follows: 'In order to meet the fluctuations in the consumption of natural gas in the South-West, and, if need be, in the rest of France by supplementing the peripheral reservoirs, and to ensure continuity of supply during the periodic overhauls of the procesing units at the Lacq plants, the Société Nationale des Pétroles d'Aquitaine (SNPA) has decided to supplement the Lacq plant by an underground storage field'[3].

To show how these three tasks will be carried out, the proposed distribution plan for Lacq gas is:

1. As from 1961 production at Lacq will be 13 mill. cu. m. per day, or, in equivalent thermal values, about 2.5 times the present French consumption of manufactured gas.

2. This quantity will be distributed among the four main consumption areas roughly as follows: (a) South-West, 5 mill. cu. m. per day, of which 2.5 mill. cu. m. per day will be in the immediate vicinity of Lacq; (b) East Central, 3.5 mill. cu. m. per day; (c) Paris region, 3.2 mill. cu. m. per day; (d) West Central, 1.3 mill. cu. m. per day.

3. The gas will be transmitted through two separate networks.

The first of these two is the South-West region's own system. It consists essentially of the following elements: (a) A 450-mm. (15.6 in.) pipe-line, which runs north from Lacq for a distance of 130 km. (81 miles); (b) a loopline running first east with a diameter first of 200 mm. (7.8 in.) and then of 125 mm. (4⅞ in.) for a distance of about 150 km. (93 miles) and, then, again with a diameter of 200 mm. in a mainly south-easterly/north-westerly direction for a distance of about 250 km. (155 miles) to a point about 30 km. (18½ miles) east-south-east of Bordeaux where these two pipe-lines join; and (c) a 150-mm. (5.8 in.) pipe-line 90 km. (55 miles) in length which runs west to Bayonne, on the Atlantic Coast.

Feeders to be supplemented

The second system, which serves the other consumption areas, consists of a joint section with a diameter of 600 mm. (23.4 in.) and a length of 220 km. (137 miles). This starts from Lussagnet, and from it three principal feeders, with diameters of 250 (9¾ in.), 450 (17.5 in.), and 500 mm. (19½ in.) will proceed over distances of 240, 210 and 350 km. (149, 130 and 217 miles) respectively towards Nantes, the East Central area and the Paris region. These feeders will be supplemented by distribution mains and spurs supplying industrial consumers and public distribution systems.

There is at the present time no peripheral storage field for natural gas. The Beynes reservoir has been reserved for coke oven gas, and it will probably be some years before the Vernon field, which Gaz de France is preparing for the storage of natural gas, can be put into service. Since the network outside the South-Western region has been designed for peak sendouts, the Lussagnet reservoir will enable total demand to be regularly covered so long as the level of production does not exceed the figure indicated above.

The reasons why the Société Nationale des Pétroles d'Aquitaine thought it necessary to build an underground reservoir in the neighbourhood (within 50 km.) of the Lacq deposit are:

1. If the storage idea had not been adopted, it would have been necessary to provide reserve capacity for the sulphuretted hydrogen removal plant, *i.e.*, to build additional facilities with a send out capacity of 3.5 mill. cu. m. per day. This would have been enough to satisfy the same demand, provided that all stoppages for maintenance were so re-arranged as to fall during the period of low consumption.

2. The necessity for ensuring absolute security of supply, especially for industrial consumers, whatever difficulties might be encountered in connection with production.

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From a paper to the North of England Section, I.G.E.

Developments in town gas production

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IN view of the position of the coal industry it does not seem right that one should stress unduly the manufacture of gas from an imported raw material, despite the fact that at the present time, processes of gas making based on oil appear to be able to supply gaseous therms at a lower cost than either the conventional carbonisation processes, or the less conventional but technically interesting, complete gasification processes. It is therefore considered desirable not to restrict this paper to a process not yet fully developed but to consider possible developments in connection with the investigations now proceeding at Solihull.

In his presidential address to the Institution in May, 1958, Dr. J. Burns[1] then pointed out that despite the marked increase in gas production since the war, the rate of increase has been much less than that of either oil or electricity. During the past five years particularly, there has been a very marked drop in the rate of expansion. These facts probably result from the relatively greater increase in the selling price of gas as compared with its competitors, which in turn is associated not only with the increase in the cost of coal, but with the increase in the price differential of gas-making coal and coal used for power generation. There are of course other factors, such as increase in freight rates, but these have to some extent been offset by a general increase in gas-making efficiency throughout the period since the end of the war.

Development of processes

The price differential between small, low-rank coal suitable for general industrial use and power generation, and coals suitable for gas-making, is likely to become greater during the next decade. Only by developing processes suitable for using such coal can advantage be taken of this differential.

Processes such as the Ruhrgas cyclone gasifier and the Rummel slag bath gasifier suffer from disadvantages in respect of the quality of gas made, while the latter process also requires oxygen for its operation.

Other gasification processes, such as Texaco and Lurgi, which operate at elevated pressures, require the use of oxygen and while the latter can operate on graded coals, the former has only operated commercially up to now on oils and natural gas.

Although the development of processes suitable for the gasification of the small sizes of the lower rank coal—whereby advantage could be taken of the favourable price differential—could benefit the gas industry, the electrical industry would be better placed than the gas industry for the utilisation of the smaller sizes of non-caking coals. If the price of small coal was preferentially reduced to encourage the gas industry to develop processes for its utilisation, then such preferential reduction would benefit the electrical industry to an even greater extent.

The influence of production capacity on the relative costs of transporting coal, oil and gas is important when dealing with capacities of the order of 240 mill. cu.ft. per day, and savings of ¼d. to 2½d. per therm may accrue, depending on the distances involved. The major areas of gas supply and low rank coal reserves are located between Manchester and London, in fact, within a band 70 miles wide between London and Manchester, approximately 70% of the total gas consumption of the country takes place, and 70% of the developed reserves of the non-caking coals of rank 800 and 900 are to be found. In this area, therefore, large gas-making stations might be located with considerable saving in costs of production.

Other parts of the country could not be so well served, though there are dense regions of gas requirement located near such principal ports as Glasgow, Newcastle, Southampton and Cardiff.

The course of development in town gas production in the future is likely to be:

1. A reduction in the cost of gas production by the concentration of gas manufacture into large stations. Supervision and labour costs may thus be minimised, and capital charges associated with large scale operation considerably reduced.
2. The development of processes capable of making use of cheaper raw materials such as the smaller sizes of lower rank coals, and at the same time being able to make use of whatever hydrocarbon feedstock might be available.
3. The location of larger manufacturing stations, either close to the large ports, or in the centres of coal fields.
4. The development of a national gas grid.

This is indeed an ambitious outlook, but it is one now generally shared by many members of the gas industry.

Hydrocarbon enrichment

For example, the 'GAS JOURNAL'[2] in 1958, commenting on annual statistics, referred to five new methods of gas supply and their investigation and development. Last May our immediate past-chairman spoke of the desirability of the development of hydrogenation processes for coal and oil, emphasising that such development was one of our great hopes for the future.[3]

Recently, Sir Henry Jones,[4] in his William Young Memorial Lecture, 1959, considered future gas demands and stressing the need to be competitive, reviewed some of the present developments, as well as work being done at the Solihull Research Centre. There is no known or established method of making town gas directly by the gasification of coal, and any gas made by the complete gasification systems now practiced requires enrichment by hydrocarbons from another source.

Even low pressure processes such as Onia-Gegi and Segas, though able to process several varieties of raw feedstock, do not offer the advantages peculiar to high pressure operation. Among these are the facility to produce gas low in carbon monoxide and sulphur and the ability to fit

in with schemes which involve long distance gas transmission. Nor can low pressure catalytic gasification systems be expected to reach the outputs from individual units of plant envisaged in future high pressure operation.

The large pilot unit now being built at Partington, for the production of 7½ mill. cu.ft. of gas per day, is based upon the Texaco oil gasification process, coupled with enrichment by the Dent hydrogenation process.

Although there are in existence large-scale, high pressure, production processes, now well proven, either for the gasification of low rank coals, *e.g.*, the Winkler and Lurgi processes, or for the gasification of oils, *e.g.*, the Texaco process, such processes require both steam and oxygen. Despite the gas being at high pressure and in a high state of purity, the basic product is unsuitable for distribution as town gas without suitable modification or enrichment. The manufacture of oxygen required for these processes, working at a production capacity of 20 to 30 mill. cu.ft. of gas per day, has been estimated to be equivalent to about 5d. per therm of the finished gas.

The use of oxygen and steam at high pressure inevitably lead to the production of a gas rich in carbon dioxide and carbon monoxide. Although both are relatively easy to remove, nearly as much effort has to be expended in taking oxygen out of the gas as was expended in obtaining the pure oxygen needed for the gasification process. Processes, therefore, which do not require oxygen but can be based on hydrogenation, are fundamentally more attractive.

Availability of coal

The traditional raw materials prior to the second world war used by the gas industry were the high volatile, strongly-caking coals found principally in the Durham and Yorkshire coalfields—and to a smaller extent in other areas —and distillate oils. Local conditions in some areas favoured the use of less strongly-caking coals on economic grounds, but because carbonisation was, and still is, the principal method of gas manufacture, coals which would yield good coke were preferred.

Since the war there have been periods of scarcity of both coal and oil and there has been a tendency to employ types of coal and oil which formerly would not have been regarded as suitable.

In 1946 appeared the Fuel Research Board's classification[5] of coals into types 100 to 900, and the relative availability of coals of different types in the different regions of coal production.

In 1948, Dr. J. G. King[6] surveyed the needs of the industry and what quantity of coal was likely to be available. Although, now of limited value, due to changes in economic planning during recent years, the basic findings of his paper indicate that during the next 100 years the output of coals of the 400 to 900 types will account for some 75% to 80% of all coal produced in the country and is likely to be in considerable excess of what is expected to be required in the gas industry.

More recently, C. Johnson[7] reviewed the needs and availability of coal of satisfactory quality and forecast availability up to 1965.

In the rather gloomy summary to the paper he points out that Great Britain, in common with most other European countries, will become increasingly dependent upon supplies of imported oil through insufficiency of home-produced coal. In view of the closing down of mines and the stock-piling of coal, his forecast as to the insufficiency of coal is, temporarily at least, very wide of the mark.

In considering the availability and suitability of coals for gas making, much of the coal mined is rejected on the grounds of high sulphur content, i.e. over 2% by weight. In view of the ease with which sulphur may be removed and recovered from gas made by high pressure processes, it is reasonable to assume that provided other properties are satisfactory, namely size, lack of caking power, ash and moisture, then the processes now in course of development will be more tolerant in respect of sulphur.

For gasification processes, lack of caking power appears to be desirable, together with evenness of grading and low ash and moisture contents. Consequently, it might be expected that if large-scale gasification of the 800 and 900 types developed, there would be a marked re-orientation of the types of coal required. Only large-scale experience will show which type of coal proves more suitable for the new processes. It is known that under high pressure in the presence of a high concentration of hydrogen, non-caking coals acquire caking characteristics. On the other hand, for the partial combustion processes, the possession of moderate caking properties does not appear to be a serious embarrassment, since the coal has to be in a finely divided state before entering the gasifier.

Whichever type of coal is ultimately used for gas making, then basing on present day practice it might be anticipated that upwards of 80% of future gas requirements will be produced from coal and probably less than 20% will be derived from oil and oil products.

Broadly speaking, the hydrocarbon oils range from natural gas and mine gas, available only in moderate amounts in two or three localities in this country, and the refinery gases and liquefied petroleum gases, through the light distillates, to gas and diesel oils and through the blended oils used largely as fuel to the residuals and the crude oils.

Although natural gas and the liquefied petroleum gases normally possess fairly definite properties, the gas available from refineries can vary in the composition and calorific value over a very wide range. [See W. F. Thorne[8] and his co-authors]. Similarly, the light distillates may vary considerably in character. Over the last few years specifications which have been submitted to us as contractors have shown considerable differences in boiling range and a big variation in aromatic content, which has a marked influence on their gas-making properties. Distillate oils supplied for the carburetted water gas process also show wide variations in gas-making characteristics, as demonstrated by Dr. R. H. Griffith.[9] Here is described a rational method of analysis for gas oils and how the thermal yield from oils obtained from different sources may vary with the different proportion of paraffinic, naphthenic, and aromatic hydrocarbons. Similar work, dealing with hydrocarbons ranging from natural gas, through gasolines, gas oils and bunker fuels to creosotes, on the enriching value correlated with the carbon:hydrogen ratio, has been carried out by the Institute of Gas Technology,[10] Chicago.

Distillate observations

Several methods for estimating the probable thermal yield from oils are described by W. J. Walters.[11] Two of the formulæ apply to distillates only, but one is claimed to be suitable for use with residual oils. In each instance the evaluation is based on thermal cracking and it is stated that there is insufficient evidence as to the suitability of any of the formulæ for the evaluation of oils for catalytic gasification.

In the light distillate range, observations made by both the Institute of Gas Technology, Chicago, and the Gas Council Research Station at Solihull, show that distillates which are richer in aromatic hydrocarbons and cycloparaffins yield less gas when catalytically hydrogenated, than do distillates consisting only of paraffin hydrocarbons.

The big variations in gas-making characteristics from

oils of superficially similar physical properties continues into the heavier oil range, where it becomes more difficult to distinguish between the potential value of different oils by means of the standard laboratory techniques normally available in laboratories attached to gasworks. Fortunately, there are available a considerable amount of published data, mostly of American origin, whereby the potential value of oils for different purposes may be assessed. This is particularly important to the new large scale development in oil gasification, namely, the Texaco process and the similar Shell process which operates under licence from the Texaco Corporation. In these processes only about 20% or less of the total heat content of the oil is consumed during the gasification phase and an error in the determination of the calorific value of the oil could have a profound effect on the calculated oxygen requirement for correct operation. With the aid of correlations published by K. M. Watson[12] and his co-workers,[13] of the Universal Oil Products Company, Chicago, and tables devised by C. S. Cragoe[14] of U.S. Bureau of Mines, it is possible to determine many of the more important properties of an oil from a few simple physical measurements which can be made with a high degree of precision.

This technique of assessment is steadily becoming of greater general value. Our own technical departments have employed it for several years, but attention was drawn to the usefulness of Watson's correlations, in the written reply to the discussion on the paper by G. le B. Diamond,[15] in which he said that the 'characterisation factor' K was obtained by dividing the cube root of the average boiling point in ° Rankine by the specific gravity. Watson has established 'characterisation factors' for pure paraffinic fractions and also for aromatic fractions resulting from the cracking of feedstocks. With the aid of these, it is possible to assess whether an oil is basically paraffinic or has been adulterated by the addition of aromatic fractions.

Refractory material risk

The total sulphur content and the ash content of oils, together with the character of the ash, must be measured directly; both occur in the heavier oils whether crude or blends of residuals. Compared with coal the ash content of oil is low, but because of its different character it can be far more harmful in its effect on refractories. The presence of such constituents as vanadium pentoxide, nickel oxide and soda, give rise to very low melting ashes which can penetrate and destroy refractory material far more rapidly than coal ash.

Established processes.

1. *Continuous catalytic reforming.*

The continuous catalytic reforming process as developed by the Hercules Powder Company, prior to the war, is used on a very large scale in America for the production of ammonia synthesis gas from natural gas and most of the ammonia production in U.S.A. is based on this process. It has a limited application in the U.S.A. for the manufacture of town gas, because it is the practice in that country to distribute gas of high calorific value[16]. It has been developed to some extent in France, where both natural gas and refinery gas are available.

Three installations for the chemical industry, using propane and butane as feedstock for the production of high purity hydrogen, have been built at Barry, Purfleet and Warrington by the Power Gas Corporation Ltd. In each instance the demand is for a pure hydrogen with a methane content as low as .2%.

Fundamentally, the process is one of the simplest. The gas to be reformed is blended with superheated steam and for the production of town gas or for ammonia synthesis with some air as well, and passed through a bed of catalyst, with a nickel content of 25 to 30% by weight, contained in a heat resisting steel tube, the latter being heated in a vertical gas or oil-fired furnace to a temperature of about 850-900°C. The reaction involved is,

$$CH_4 + H_2O = CO + 3H_2$$

A variation of this process came into operation at Whitehaven approximately five-and-a-half years ago for the reforming of mine gas[17]. In this instance, the furnace tubes are horizontal and the catalyst employed has a much lower proportion of nickel.

The North Eastern Gas Board have decided to install a gas-making unit at the Whitby gasworks to reform natural gas drawn from wells on the moors near Whitby. It will comprise three two-tube furnaces, two of which will be capable of the full load requirement of 1¼ mill. cu.ft. of 500 B.t.u. gas per day, with one furnace as a standby. Provision will be made to store butane for emergency use, but production per furnace will drop to about 80% of the rated full load capaciy when operating on butane.

Future developments

It is feasible that future development of the importation of methane, either by pipe-line from the Sahara or by sea in liquid form, could result in a bigger demand for this type of process. The Guernsey Gas Light Company is also to install a continuous catalytic reforming unit to produce 1¼ mill. cu.ft. of 450 B.t.u. gas per day from butane.

2. *Cyclic catalytic reforming.*

The Segas and Onia-gegi cyclic catalytic reforming processes, introduced into this country during the past 10 years, have, to a large extent, lost their novelty, but comments made by Mr. W. K. Hutchinson, to the discussion on a paper by Burns and Stewart,[18] compared the Romford and the Isle of Grain developments. Both were planned at the same time, but with a different approach; the former is tailor-made to suit a special product, namely purified refinery gas, but the latter was intended to process whatever feedstock should be available from the refinery where it is located.

3. *Coal gasification.*

Although complete gasification of coal in the form of bituminous producer gas has been practised for nearly a century, it still excites some interest in its most recent developments. Experience in low pressure operation at Watford and Kensal Green does not suggest that these processes will prove of major value in the future, since the provision of the right fuel is important, and the gas is of relatively low calorific value, and the process has none of the advantages of high pressure operation. They are not likely to develop into high capacity units.

Interest in the Lurgi process in this country, has increased with the building by the Scottish Gas Board of the plant at Westfield. Further development is to be expected by the West Midlands Gas Board.

The process involves the gasification of small, graded, non-caking coals, in a mixture of relatively pure—95%—oxygen and steam, at pressures normally above 20 atmospheres. Because of the high pressures, gas velocities are low, permitting the use of coal particles as small as 3 mm. or ⅛ in. Tests made in Germany after the war demonstrated the feasibility of gasifying successfully the whole range of British non-caking coals outside the carbonising range, namely types 702 to 902, which may account for 40%

of the total coal production during the next 80 years. Ash content up to 30% may be tolerated.

While in some instances the object of gasification is the production of gas for synthesis purposes, the value of the process for towns gas manufacture has already been amply demonstrated on a large scale.[19] At Morwell in Victoria, Australia, planned production was to be 30 mill. cu.ft. per day by 1960 and 60 mill. cu.ft. per day by 1965, but output was limited to 15-18 mill. cu.ft. per day because of an inadequate supply of brown coal briquettes.

Although the more reactive brown coals give gas after suitable purification of a higher calorific value than do the black coals, in Australia it has been necessary to enrich the gas from pressure gasification to 500 B.t.u. per cu.ft. by the admixture of refinery gas, in order to bring it up to the same quality as the gas normally distributed.

With black coals, it is expected that a greater degree of enrichment will be necessary than for brown coals, the calorific value of gas made in this case being in the range of 400 to 420 B.t.u. per cu.ft.

Basically, the chemical reactions involved in the process are:

1. Combustion of carbon to provide heat for reaction,
$$C + O_2 = CO_2.$$
2. The steam carbon reaction,
$$C + H_2O = CO + H_2$$
which absorbs heat.
3. The water gas reaction, which increases the partial pressure of hydrogen,
$$CO + H_2O = CO_2 + H_2.$$
4. Hydrogenation of the coal substance,
$$C + 2H_2 = CH_4.$$

It is the latter reaction which enables gas of relatively high calorific value to be obtained. The concentration of methane in the product gas increases steadily with increasing pressure, reaching an optimum value somewhat in excess of a working pressure of 20 atmospheres, or 300 p.s.i[20].

Disadvantages of coal

A disadvantage of the gasification of black coals is the tendency to acquire caking properties, due to hydrogenation taking part in the upper layers of the fuel bed. To avoid the development of caking properties the charge must be stirred.

A second disadvantage is the need for a supply of oxygen of adequate purity. A considerable proportion of this oxygen appears as oxides of carbon—over 30% of carbon dioxide in the crude gas and 15% to 20% of carbon monoxide. The former is removed during the purification stage by washing with water, but the latter remains, so that the purified gas may contain up to between 20% and 30% of carbon monoxide by volume, which is not in keeping with present day tendencies towards non-toxic gas. In any future development it is likely that a CO conversion stage will be incorporated to reduce the CO content to a low level. In any case the gas will have to be enriched with refinery gas as is projected at present at Westfield, with gas from the hydrogenation of oil, or by methane made by direct synthesis.

4. *Partial combustion at elevated pressures.*

A process which has attracted world-wide attention during the past five years is the partial combustion of hydrocarbon gases and oils at elevated pressures. Like the Lurgi process, it makes use of relatively pure oxygen and steam. It was developed almost simultaneously in America by the Texaco Development Corporation, and in the Netherlands by Shell.

The process was primarily developed for the production of synthesis gases. Unlike the Lurgi process, its low working temperature promotes the destruction of methane down to less than .4% of the product gas, which consists principally of carbon monoxide and hydrogen with smaller proportions of carbon dioxide and nitrogen. Nitrogen largely results from impurities in the oxygen supply.

When applied to town gas manufacture, the necessary CO conversion step must be included in the gas treatment if the final gas is to be non-toxic while some form of CO_2 removal must be practiced. The final gas is substantially hydrogen which must be enriched and densified by incorporation of rich gas of high calorific value and, when necessary, with nitrogen.

As indicated by du Bois Eastman[21, 22], the actual chemical reactions are exceedingly complex but they may be simplified into what is substantially a two-stage reaction mechanism. The first stage is by the exothermic reaction,
$$CH_4 + 2O_2 = CO_2 + 2H_2O$$
This reaction proceeds so far to the right that no measurable oxygen remains. Since the quantity of oxygen supplied is much less than that required to react with all the methane, surplus methane can then react with either CO_2 or steam as follows,
$$CH_4 + CO_2 = 2CO + 2H_2$$
$$CH_4 + H_2O = CO + 3H_2$$
These reactions both absorb heat and it is necessary to adjust the quantity of oxygen so that the temperature is maintained at the correct level in the reactor and a negligible amount of methane is left unchanged, without permitting the reactor to become too hot.

Other reactions which can take place are the water gas reaction,
$$CO + H_2O = CO_2 + H_2$$
and the producer gas reaction wtih the formation of carbon.
$$2CO = CO_2 + C$$

When dealing with oil or tar, the reactions become more complex, but the ultimate result is the same as for oxygen and methane except that when dealing with fuel oils, conditions are adjusted to leave a certain amount of uncombined carbon which amounts to between 2% and 4% of the carbon fed as oil. It is a carbon easily wetted by water and can be scrubbed from the gas and either recovered by filtration, or by a system of oil extraction whereby it can be recycled though the generator and ultimately consumed.

Ash in the oil does not normally interfere with the operation, provided that suitable refractories are employed in the reactor and the ash is lost in the washing water used for scrubbing out the carbon.

Thermal efficiency

The thermal efficiency of the process reaches a maximum value of about 84% or perhaps a little higher when the oxygen consumption per 1,000 cu.ft. of product hydrogen and carbon monoxide reaches about 260 to 270 cu.ft.

Allowing for energy requirements for oxygen plant, process steam, etc., the overall thermal efficiency is estimated at about 70%, which is similar, or perhaps a little higher than, the 67% estimated for the Lurgi process.

The gas is substantially free from impurities other than sulphur and in practice, approximately 90% of the sulphur in the fuel appears as hydrogen sulphide and most of the remainder as carbonyl sulphide, with only a minute quantity of carbon disulphide.

Processes not commercially established.

5. *Methane synthesis.*

The synthesis of methane from purified carbon monoxide and hydrogen attracted considerable attention in the years immediately following the war, and experimental work

was carried out under the auspices of the Gas Research Board.[23, 24]

By reacting pure carbon monoxide with pure hydrogen, in the presence of a suitable nickel catalyst, a gas can be produced with a c.v. up to 1,000 B.t.u. per cu.ft., in accordance with the reaction,

$$CO + 3H_2 = CH_4 + H_2O$$

Although pilot plant work at a capacity of about 500 cu.ft. per hour of 500 B.t.u. gas demonstrated the reliability of the process, large-scale work was not undertaken. At that time, synthesis of methane appeared to be competitive with oil enrichment in the c.w.g. process, because of the relative costs of coke and oil.

The gases used for synthesis must have a very high degree of purity and must contain no more than .002 grains of sulphur per 100 cu.ft.; the desired standard can be reached, as it has already been achieved for the purposes of Fischer-Tropsch synthesis.

Technical difficulties

The most undesirable feature of methane synthesis is the reduction in potential heat as gas which thereby increases the overall cost of gas production and reduces the overall thermal efficiency. When enrichment is only of a minor order, this might not be serious, but it has been estimated that enrichment of Lurgi gas from 400 to 450 B.t.u. per cu.ft. could increase the overall cost of production by 5%. Technical difficulties are associated with deposition of carbon on nickel catalyst and effective dissipation of the high heat of reaction, but such difficulties were proved to have been overcome during a five months continuous test period, operating at a pressure of 20 atmospheres.

6. *Oil hydrogenation.*

Research into the hydrogenation of oil for the production of rich gas has been proceeding both at the Institute of Gas Technology, Chicago, and under the auspices of the Gas Council, for a number of years. The former is interested in the direct production of gas having a calorific value of 1,000 B.t.u. per cu.ft., which gas could be admitted directly to pipe-lines in America. The latter is more concerned with the economical production of a gas suitable for the enrichment of Lurgi and Texaco gases. In America, the need for solving this problem is less urgent than in the U.K. at the present time, and it is probable that the work at Solihull is much more advanced than that in Chicago.

Although pilot work is proceeding in Chicago, published data so far appears to relate only to laboratory studies[25].

The Gas Council Research team[26] employed an 11¼-in. i.d. reactor, 22 ft. long, suitably insulated, inside a 30-in. i.d. shell, to which 200,000 cu.ft. per day of hydrogen of 95% purity, preheated to 550°C. in a salt bath, could be supplied. Operation could be at pressures up to 35 atmospheres.

The technique adopted was to inject oil into a bed of coke particles graded 36 to 150 mesh (B.S.S.), fluidised by the stream of hydrogen used for hydrogeneration. The operating pressure in the tests reported was usually about 32 atmospheres but it is reasonable to expect that with suitably designed plants, any pressure between 20 and 50 atmospheres could be used.

Basically the reaction involved is,

$$CnHm + H_2 = Cn\,H_{2n+2}$$

or, more simply, oil plus hydrogen forms saturated gaseous hydrocarbons. In the pilot plant studies, it was demonstrated that all qualities of feedstock, ranging from light distillate through gas oil to 3,000-second oil and crude oil, were satisfactorily hydrogenated.

Distillates which could be vaporised before entering the coke bed were apparently used without difficulty, but when dealing with heavier feedstocks, it was necessary to atomise them in the bed, and because of a tendency towards agglomeration and the caking of the particles, it was necessary to develop the technique of employing a moving burden—that is, an actual recycling of the fluidised bed in order to avoid the growth of agglomerates.

Conradson carbon was deposited on the coke, and consequently, coke had to be run off at intervals through a lock hopper. There was some growth in particle size which might involve ultimately the screening out of larger particles.

From a heavy fuel oil of 3,000 seconds Redwood No. 1 with a Conradson carbon content of 11%, a gas yield, together with benzene, totalling 1.33 therms per gal. of oil was obtained, of which 1.2 therms appeared as gas and the remainder substantially as benzene.

The reaction takes place at a temperature between 700° and 900°C., and the evolution of heat is so high that on a large scale, reaction temperatures could be maintained by preheating the hydrogenating gas to between 300° and 600°C. by heat exchange with the outgoing gases.

Below 700°C. the reaction proceeds too slowly, while above 900°C. tar vapours tend to crack and form soot. The employment of a fluidised bed enables control over the working temperature to be maintained. Thorough mixing of oil with hydrogen is absolutely essential, for under the working conditions in the absence of hydrogen, oil can rapidly decompose depositing carbonaceous matter which leads to the building up of agglomerates already referred to.

With light distillates at a working pressure of 32 atmospheres, and a partial pressure of hydrogen of 30 atmospheres, it was demonstrated that calorific values of between 580 and 863 B.t.u. per cu.ft. could be obtained. In the case of gas oil, the calorific value of the product was 559 B.t.u. per cu.ft., and when using crude oil it was approximately 600 B.t.u. per cu.ft., while even with heavy fuel oil it has been shown that a calorific value as high as 500 B.t.u. per cu.ft. can be achieved without having difficulty with agglomeration and caking.

Lurgi improvements

The composition of the gases obtained from different fuels are shown in the table:—

Gas constituent	Light distillate	Gas oil	Crude oil	Heavy oil
CO_2	·25	·4	·35	·1
CnHm ..	·2	—	·25	·1
H_2	68·55	68·0	64·2	75·15
CO	1·1	·95	1·35	·75
CnH_{2n+2} ..	27·35	28·2	32·4	22·6
N_2	2·55	1·85	1·45	1·3
Cal. value B.t.u. per cu. ft. ..	580	559	597	499

The above gas analyses relate to gases from which benzene has been removed.

It has been estimated that operation with light distillate in conjunction with a Lurgi plant for the production of 500 B.t.u. gas of a density of approximately .5, the overall output of the Lurgi plant could be increased by 50% without requiring any more oxygen or steam. It would appear that oil hydrogenation is perhaps the simplest way of achieving the necessary improvement in performance of Lurgi gasification, except when gases of high calorific value are already available.

A most interesting feature of the hydrogenation of oil

is the conversion of the oil to saturated hydrocarbons, either in the form of methane and ethane or in the form of so-called parent aromatic hydrocarbons. When hydrogenating gas oil, the liquid product consisted essentially of benzene and naphthalene with practically no other type of hydrocarbon. When hydrogenating crude oil and heavy fuel oil the liquid product consisted of benzene, naphthalene and other higher constituents.

At the present time a 1 mill. cu.ft. per day unit is being operated experimentally at the Solihull Research Station. Light distillate is being hydrogenated and a supply of hydrogen is being obtained by the reforming of butane in a low pressure continuous catalytic reformer. Ultimately it is intended that the required hydrogen will be obtained from part of the product gas.

Associated with the developments involving the hydrogenation of oil is the direct production of benzene and naphthalene by a similar technique, from light distillate. This work so far has apparently been carried only as far as the laboratory stage, but it is most interesting in respect of future developments[27].

Liquid storage principle

In the original paper there was a diagrammatic representation of a proposed plant for the production of sulphur-free town gas and pure benzene and other aromatic hydrocarbons by the hydrogenation of light distillate. It included a methane reformer of a type not yet developed, but working on the same basic principle as the continuous catalytic reformer to be installed at Whitby, to make the hydrogen.

7. *Peak load gas from methanol and light distillate.*

Another interesting research development at Solihull relates to the possible meeting of peak loads at a base load plant, by employing the principle of liquid storage. This could be of significance on large scale operation at sites where underground storage might not be available.

The proposal is first the synthesis of methanol from pure carbon monoxide and hydrogen under pressure in the presence of a catalyst in accordance with the reaction,

$$CO + 2H_2 = CH_3OH + 0.176$$

therm per therm of methanol.

The process of methanol manufacture is already well established in the chemical industry, and could readily fit into a system of gas manufacture employing high pressures and the production of gas rich in carbon monoxide and hydrogen as is obtained from a Texaco generator.

Small-scale work has demonstrated the possibility of causing steam and methanol to react in the presence of a nickel-alumina catalyst at a pressure of about 25 atmospheres, and by the controlled addition of air, together with carbon monoxide conversion, a non-toxic gas could be produced, the calorific value of which could be controlled easily within the range 450 to 500 B.t.u. per cu.ft. and at the same time the specific gravity could be controlled from as high as .50 to as low as .39. Overall thermal efficiency based on methanol used is of the order of 88%, and based on the carbon monoxide and hydrogen required to produce the methanol, is of the order of 75%.

An alternative approach to the meeting of peak loads is in the employment of light distillate. Since this material contains sulphur, it requires purification. Small-scale work has demonstrated the possibility of removing sulphur completely, by first hydrogenating the light oil in the presence of molybdenum sulphide catalyst at 360°C., followed by absorption of the hydrogen sulphide formed in alkaline iron oxide at 300°C. The process operates in the pressure range 10 to 25 atmospheres. Such purified distillate could be prepared continuously and stored to meet peak load requirements.

It has also been demonstrated that light distillate can be made to react with steam and air in two stages in the presence of a nickel alumina catalyst, both at atmospheric pressure and at 25 atmospheres, to yield a gas rich in methane and low in carbon monoxide and suitable for distribution as town gas. By various modifications, calorific value and specific gravity of the finished gas can be varied to suit substantially any requirement. It has been estimated that the capital cost for equipment needed for this type of plant makes these processes attractive from the point of view of meeting peak loads[28].

8. *Hydrogenation of coal.*

Hydrogenation of coal has been successful in the laboratory for nearly 50 years. Patents were taken out in 1914 by Bergius, while during the last 25 years, coal hydrogenation reached the stage of commercial development in Germany, Japan and England. Nevertheless information relating to means for the production of rich gas, suitable for town gas purposes, has resulted largely from the research work sponsored by the Gas Research Board, which prior to the war, through its Joint Research Committee, authorised an investigation into the study of the Lurgi process. This proceeded on a relatively small scale for a number of years and the results of these fundamental studies were published in association with the name of Dr. F. J. Dent[29].

These studies led to the consideration of direct hydrogenation of coal without the employment of any oxygen during the gasification stage. When producing methane by reaction between carbon monoxide and hydrogen there is a loss of potential heat, but during the hydrogenation of coal there is an increase in the potential heat of the gas due to the gasification of carbon equivalent to 80% of the potential heat of the carbon gasified. It appears that hydrogenation is the most efficient gasification reaction as yet investigated. An attractive feature of this approach is that it would ultimately be able to deal with coal dust and the smaller sizes of coals now not suitable for gas generation[30]

Slagging gasifier development

According to Dr. Dent[31], the most difficult problem associated with such a system is the development of the steam oxygen gasifier for the powdered residue. Here fluidised techniques do not appear to be suitable for obtaining gasification to completion. Until this particular problem is solved, the full scale development of satisfactory hydrogenation of small coal may be retarded. Nevertheless, progress is being made and our latest information is that a coal hydrogenator rated at about 1 mill. cu.ft. of gas per day has been tried out on a carbonised residue, but experience is not sufficiently advanced to permit the use of coal direct. Consequently, it is to be expected that coal hydrogenation will take a number of years to develop.

Work has been done on the development of a slagging gasifier[32]. This work was done from the point of view of improving efficiency of gasification with oxygen and steam by saving steam and encouraging reaction between hydrogen and coal to produce methane. It may not prove to be of real value, for owing to the loss of heat in the coal ash when discharged as slag, the efficiency is not as high as is desired, while there are problems associated with conditioning the ash in order to form a slag. Furthermore, the product is of low calorific value and still requires enrichment.

Coal hydrogenation could be the ultimate answer to the production of rich gas directly from coal in the most efficient manner.

Parallel with these developments are the large-scale

development of the peak load type of plant involving either reforming of light distillate or of methanol, in the presence of a suitable catalyst. These latter processes being simple and continuous could be of great value for meeting peak loads without requiring too much storage capacity.

The effective development of a hydrogenation of oil system requires the development of a methane reformer operating under pressure whereby the hydrogen is made. If coal and oil are to continue to be used together, then the slagging generator together with a pressure reformer and oil hydrogenation could be an effective answer, but ultimately they should lead to the direct hydrogenation of coal which will eliminate the need for enrichment by the hydrogenation of oil. It will be appreciated that the resolution of these problems is a long way in the future.

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DISCUSSION

Mr. W. R. Garrett, Constructional Engineer, Northern Gas Board, opening the discussion: My immediate reaction to Dr. Milner's paper was 'Where does the Northern Gas Board go from here?' It is true that very careful study is being given to the gridding up of the country, but, if you will remember, Dr. Burns in his paper put forward the argument that as the major areas of gas supply and low rank coal reserves are located between Manchester and London, this favours the principle of concentration of gas manufacture in large generating stations located close to the supplies of raw material. From this it would appear that there will be little advantage to the Northern Gas Board from these very large plants which are being established. In many cases these plants will be based on imported fuel and also on indigenous fuel. I do not visualise the Northern Gas Board receiving a supply from these grids within, say, the next 5-10 years.

With regard to other processes, I have been given the opportunity to visit Westfield. I was very impressed with the work which was being carried out there, but the gas may be estimated to cost about 11d. per therm, whereas at Howden the N.G.B. are very disappointed if they do not produce a gas at a price of 8d. per therm. It is true this Lurgi gas will be very much better as regards the toxic factor, but even if we allow ½d. per therm for the removal of carbon monoxide, etc., Lurgi gas still appeared to be a very expensive gas compared with N.G.B. standards.

While Dr. Milner's paper gives a lead as to what to think about, the ultimate solution of the problem of what to do is still obscure. In the North, the gas boards are virtually sitting on coalfields, but with coal which, according to present methods, is unsuited for gasification. The N.G.B. has gone into the field of oil gasification, but having regard to their position geographically it does not seem right to depend on imported fuels when large areas of coal are on their doorstep. In my opinion, Lurgi gasification and hydrogenation of coal appear to be rather expensive and many years ahead; can Dr. Milner give a lead as to what they can do?

Dr. Milner said he did not think Lurgi gasification was going to be the answer. In his opinion, Dr. Dent's approach was more likely to be the ultimate end. It had been envisaged that the hydrogenation of coal could be done in units of the order of 100 mill. cu.ft. per day in a comparatively small unit and might also be workable in smaller size units down to about 10 mill. cu.ft. per day, which might ultimately fit into Northern Gas Board requirements if it should run out of the supply of suitable carbonising coal. He did not think, as things were at the moment, that these developments, which were really a review of research going on, could be regarded as likely to be of immediate benefit to the Board. Dr. Milner realised this did not answer Mr. Garrett's question; no answer was readily available.

Mr. B. Richardson, Northern Gas Board, said he had

found Dr. Milner's paper very easy to read. Regarding plants now being set up as commercial developments, whatever advantages they appeared to have had been more or less offset by their disadvantages. In his opinion these included the very high carbon monoxide content which must be reduced which would cost 1¼d. to 1¾d. per therm.

Furthermore, detoxification involved the replacement of carbon monoxide by hydrogen, which had a much lower nett calorific value, so that from the users' point of view the process was very inefficient. In his opinion the removal of carbon monoxide and substitution of hydrogen was a wrong step.

Mr. Richardson went on: I am entirely in agreement with Dr. Milner when, referring to the Lurgi plant, he points out that in this system of total coal gasification carried out under pressure and in the presence of oxygen and steam, nearly as much effort is expended in taking expensive oxygen out of the gas in a useless form as putting it in. For this reason I do not regard this process with any great favour. Dr. Milner in the course of his paper speaks of the overall efficiency of a Lurgi plant as 67%, but I would be inclined to place it lower than this figure.

From my experience of detoxification, I would say that so far a suitable catalyst for this purpose has not been evolved, except perhaps for blue water gas which contains little, if any, hydrocarbon bodies. When dealing with carburetted water gas I have found that the lives of all catalysts used up to the present even when guarded by a pre-catalyst have been too short to render their use economic.

Dr. Milner: It is perfectly true, as Mr. Richardson says, that the detoxification of gas is a thermally inefficient process. While detoxification has been of casual interest to the gas industry for some 25 years it has only become of pressing interest largely as a result of political agitation. If the gas industry could ensure the elimination of accidental deaths from carbon monoxide poisoning this would go a long way towards destroying the demand for detoxification by a politically-minded public. With regard to suicide by coal gas poisoning, it is possible that the number of deaths would not decrease—other methods are available. Perhaps the main thing is to ensure that the dangers associated with carbon monoxide are avoided and the problems for the gas industry to consider are principally (i) the leakage of gas from fractured mains and (ii) the careless use of gas appliances.

Technical aspects

With regard to the technical aspects of detoxification, so far as is known there is only one gas which is easy to deal with and that is blue water gas; other gases—coal, c.w.g. or oil gas—contain constituents which destroy the activity of the iron oxide catalyst normally used for CO conversion. Small-scale work has led us to believe we could protect the conversion catalyst against the insidious attack of the gum-forming constituents. But unless one of the gas boards is sufficiently interested and will let us practice on a large scale we cannot do more than claim that we know the answers.

Mr. N. Henderson, Assistant Manager East Coast Gas Grid, N.G.B., said that he did not understand Dr. Milner's statement that any reduction in the price of small coal would benefit the electricity industry more than the gas industry. He went on: We are paying £5 to £10 per ton for coal and if we could get a reduction of, say, 30s. or more, the cost of production of gas could be reduced. The gas manufactured by the Board costs 8d. to 1s. per therm and a reduction of 30s. in the price of coal would be equal to a reduction in the cost of manufactured gas of 4d. per therm. What proportion of the electricity cost is taken up by the cost of coal as against that of the gas industry?

In a final question he asked Dr. Milner what he thought of coke for steel making; whether coke ovens would remain or would some other type of plant be substituted.

Dr. Milner: With regard to this item on [p. 2] I was trying to point out that if there was a further reduction in the price of small coal with a view to encouraging the gas industry to use it, then any such reduction would apply in the case of the electricity industry. Naturally, the coals you want reduced in price are those which are easy to carbonise. The electricity industry already makes use of the cheapest coal and if you make coal any cheaper then their price is automatically lowered.

With regard to the question—will coke ovens always be with us—then, again, this is outside my scope of work; so long as coke is used for iron smelting then of course it is to the benefit of (say) Ashmore, Benson, Pease & Company because they make blast furnaces which make use of coke.

There are other processes coming to the fore, namely, ore beneficiation by means of gas, and one of the possible future developments of a process such as Texaco or the Shell partial gasification would be the production of suitable reducing gas, and here, what is required is a gas rich in carbon monoxide rather than hydrogen. I think, so far as we can say in respect of our own working lives, that is, for the next 20 to 30 years, coking coals will be very much in demand.

UNDERGROUND STORAGE

(Continued from p. 101)

3. The need to regularise the shape of consumption curves in the South-West region.

Within this framework, the necessary storage capacity has been determined from statistical estimates based on a study of the different markets. A stock of 300 mill. cu. m. on hand at the beginning of the withdrawal period will enable demand to be satisfied while production is maintained at a constant level, with a probability factor of not more than .5% for failure to meet demand.

The origin of the Rostoki reservoir, function of which at first was to meet local seasonal demand, is somewhat different from that of the reservoir at Lussagnet, but in practice the functions performed by the two are now very similar. At the present time, the Rostoki storage field, which is situated 70 km. (42½ miles) from Strachocin in southern Poland, where there is a natural field, uses an old well near a long-distance transmission system and performs the following functions:

1. It provides facilities for meeting the increasingly large local seasonal demand in winter due to the extension of heating (2,500 cu. m. per hour in summer, as compared with 9,000 cu. m. per hour in winter).
2. It ensures security of supply.
3. It improves the utilisation of the long-distance transmission system by regularising supplies of gas for transmission from the Strachocin field.

The existence of this reservoir has made it possible to sell 12 to 15 mill. cu. m. of natural gas a year, which represents 2% of all natural gas deliveries in Poland.

[To be continued]

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GAS ON THE CONTINENT

Cracking of methane under pressure

THE cracking of high calorific gases was, before the last war, almost exclusively carried out at low or at atmospheric pressure; today chemical synthesis is normally carried out at considerable pressure. The methane would normally be supplied under pressure as in the plant for making synthesis gas from methane here described at a Hamburg gasworks and hence the plant can most economically operate at pressure.

Three decomposition processes are available to the methane when mixed with carbon dioxide and steam or water gas. These reactions are first the genuine cracking reaction to hydrogen and soot, secondly the reaction with steam to produce carbon monoxide and hydrogen and lastly the reaction with carbon dioxide to produce carbon monoxide and hydrogen. All three reactions are endothermic requiring 800, 2,190 and 2,630 k.cal. per cu.m. at S.T.P., respectively. Curves of mass balance against temperature plotted for different pressures shows that with increasing pressure an increased temperature is required.

The heat required for the reaction can be supplied by one of four methods, namely (a) by supplying oxygen with the charge either in the form of air or oxygen, (b) by external heating through metal or ceramic tubes, (c) by recuperative heating from exhaust gases from some furnace, (d) by means of a moving heat exchange matrix heated by some external source of heat. Considered in detail, it is clear that only (a) is practicable for operation at pressure, since the temperatures involved are of the order of 1,200 to 1,500°C. without a catalyst or 800 to 1,000°C. with a catalyst. It also has the advantage of removing simultaneously the soot formed by cracking.

The plant used in Hamburg was developed by Lurgi and can be considered as a fully commercial unit. Arranged in duplicate each unit produces 400,000 cu.m. per day. One difficulty is that the catalyst is subject to poisoning by sulphurous gases, which are certain to be present in such raw gases.

Incoming refinery gas is therefore scrubbed of H_2S in a large plant which leaves it with a content of only 20 to 30 mg. sulphur per cu.m. in a predominantly organic form. The raw gas is first saturated with steam and then heated to 500°C. in a counterflow heat exchanger. After mixing with the preheated air, the gas is taken to the nickel contact catalyst at between 800 and 850°C.

The reactor vessel is provided with a jacket boiler which generates steam at 12 atmospheres, half of which is used in the process and the other half supplied to the plant's steam system.

The heat of the gases leaving the process is removed successively in the gas heater, the air heater, the feed water to the process, a spray cooler and a final tubed cooler. In order to provide a final product for town gas distribution with a calorific value of approx. 4,500 kcal. per cu.m., the output of the cracker is mixed with a quantity of refinery gas approximately equal to that originally supplied to the cracker. The make up of the various gases can be seen from the table, from which it is clear that the nitrogen in the air remains in the final product as diluent. *H. Hiller. Gas-Wärme, Vol. 8, No. 5, May, 1959.*

Composition and quantities per unit, cracking refinery gas

	Refinery gas	Cracked gas	Town gas
CO_2	0·7	5·4	3·3 %
$C_n H_m$	0·9	—	0·5 %
O_2	0·3	—	0·2 %
CO	1·9	10·7	6·7 %
H_2	54·0	44·1	50·3 %
CH_4	24·0	0·7	12·3 %
C_2+, C_3+	12·0	—	5·7 %
N_2	6·2	39·1	21·0 %
C.v.	6,700	1,700	4,200 kcal/Nm³
Quantities :			
(through the plant)	2,500	8,300	Nm³/h
(to be mixed) ..	9,500	—	17,800 Nm³/h

Rotating grate producers at Baden, Switzerland

BADEN gasworks, wiht a yearly production of 29 mill. cu.m., has used vertical chamber ovens since 1921 and when it became necessary to extend the plant, the opportunity was taken to extend mechanisation also. Previously the coal-grinding plant had been supplied by a pneumatic shovel tractor and the pulverised coal was delivered automatically to the ovens. The coke discharge, dry quenching and coke breaking plant was operated by one man only per shift. During the period of mechanisation from 1942, the labour force had been reduced from 33 to 14 with almost the same wages bill. The carbonising plant comprises a five-oven block and a seven-oven block divided into four- and three-oven units, the three-oven unit being normally kept as a cold reserve; the ovens are operated on a 24-hour basis.

It was decided to replace the existing step grate producers by a rotating grate mechanical producer with automatic ash removal. To ensure reliability, two producers separated from the oven blocks were to be provided. Although the heating of large coke-oven plants by clean cooled producer gas from a central plant is the standard practice, such refinements would be out of proportion in this case and the heat lost would reduce the overall economy. The system chosen would supply hot gas to the ovens by the shortest possible route. Coarse dust is removed by cyclones at the producer outlet and fine dust is deposited at the entry to the recuperator from which it is removed every two to three months.

After two years operation no dust has appeared in the heating flues and the slide valves, which gave trouble with the step-grate producers, have not suffered from slagging. The new producers have been sited in the position occupied by an old four-oven bank, i.e., in the oven house itself and the space occupied by the old producers has been used to install a recuperator, to raise the gas temperature from 450°C. to 600°C. The heat thus removed from the waste gases is small so that the waste heat boiler output was not affected by the above alterations. The producers themselves raise steam at 75 p.s.i. from the jacket boilers which are parallel with the existing steam system. *T. Zambetti, Monats-bulletin des Schweiz. Vereins von Gas-und Wasserfachmännern. Vol. 39, No. 5. May, 1959.*

NEWS SUPPLEMENT

Royal Dutch/Shell in methane tie-up

NEW COMPANY SHOULD SPEED DEVELOPMENT

INTERESTS of the Royal/Dutch Shell group of companies, Continental Oil Company and the Union Stockyards & Transit Company of Chicago, in the liquefied natural gas field are to be developed through the medium of a jointly-owned company to be known as 'Conch International Methane Ltd.'

Continental Oil and Union Stockyards, both American companies with head offices in Houston and Chicago respectively, have pioneered research in the liquefied natural gas field through their joint subsidiary, Constock International Methane Co. Ltd.

Constock, after much costly research in transporting natural gas in liquefied form at a temperature of minus 258°F. have acquired valuable know-how and patents in this entirely new field. Until the development of Constock's new system there had been no means of transporting methane by sea as a liquid.

Successful cargo

As a result of this work Constock and the Gas Council participated through a joint company, British Methane Ltd., in a project to ship liquid methane from Lake Charles, Louisiana, to the United Kingdom.

It will be recalled that the first cargo was successfully carried in February 1959, by the Methane Pioneer, a tanker jointly owned by Constock and the Gas Council, since when this ship has continued regularly to deliver cargoes of 2,000 tons liquid methane to the North Thames Gas Board's special depot at Canvey Island, Essex.

Distant markets

Shareholders in Conch International Methane Ltd., will be Canadian Shell Ltd., (a company of the Royal Dutch/Shell group), Continental Oil and Union Stockyards.

'The combination in the new company of Constock's technical knowledge and Royal Dutch/Shell's experience of worldwide operations should accelerate the development of commercial transportation of methane in liquid form from producing countries to distant markets in the industrial areas of the world,' said a statement issued last week.

Change of address

The London address of the British Welding Research Association is now 19, Fitzroy Square, London, W.1. Telephone: EUSton 9595/6.

Three B.P. bores produce gases

THREE of six bores, being drilled in the Gainsborough, Lincolnshire, district by the British Petroleum Company have produced oil and two of them gases. One of the bores, at the hamlet of Yawthorpe, four miles from Gainsborough, is producing nine tons a day in commercial quantities.

At a bore in Gainsborough town, oil was found at 3,300 ft. and 4,300 ft. and gas at 4,700 ft. The gas is likely to yield 100 mill. cu.ft. a day. A bore in a recreation field in Gainsborough is now down to 5,000 ft. and is expected to produce a record yield when it is tapped.

'100,000 NEW CANADIAN GAS USERS IN 1960'

CANADIAN gas utilities will have nearly 100,000 new customers in 1960, Mr. N. E. Tanner, President of the Canadian Gas Association in Toronto has predicted.

Pointing out that natural gas service has been supplied to over 900,000 Canadians in the last decade, Mr. Tanner stated that there were now more than 1,100,000 users.

'The coming year will, without doubt, see a continuation of the rapid expansion of the gas industry. Utility sales and service programmes will be widened to encompass an even greater portion of the Canadian population,' he said.

Competition for the appliance sales market would gain in intensity between gas, oil and electricity. Rapid gains had been made last year in the sale of gas water heaters, furnaces and clothes-dryers. Aggressive marketing and sales methods would be used to further increase the sale of all gas-fired appliances.

Lord Morrison of Lambeth pictured when he opened the South Eastern Gas Board's new showroom at Lewisham on January 11. He is accompanied here by Lady Morrison and Mr. R. N. Bruce, the Board's Chairman. 'The Board is to be congratulated very warmly on the equipment, layout and general attractiveness of this showroom,' said Lord Morrison. He added that he thought competition between gas and electricity was good for both the industries and the consumer.

Junior papers discuss the means of production, distribution, service and sales

'SHORT paper day' of the East of Scotland Junior Gas Association, held at Dunfermline on January 9, introduced three topics—production, distribution, and service and sales.

In a paper on 'Therms from Sewage,' Mr. W. B. Townsend, Works Superintendent of the Border District of the Edinburgh and South Eastern Division of the Scottish Gas Board, said that in June, 1959, Hawick Town Council installed a Kessner-type sewage disposal unit.

Describing the 'gas producing department' of the sewage works, he said that the sludge deposited in the primary sedimentation tanks was removed via pumps to the consolidation tanks, and then charged into the heated sludge digestion tank, a concrete construction with a floating roof. The sludge was continuously circulated through a gas-fired sludge heater.

The heating and stirring accelerated the natural process of breaking down the organic materials in the sludge and the formation of the sewage gas. The gas collected under the dome of the floating roof and was conducted away to the gasholder (capacity 2,500 cu.ft.).

Between the sludge digestion tank and the holder was a small set of purifiers, consisting of two small concrete boxes, each filled with about 10 cwt. of Manox. There was at the outlet of the digester approximately 10 grains per 100 cu.ft. of H_2S in the gas.

Coincidence

He pointed out that in the normal sewage works set-up there would be no gasholder or purifiers as any surplus gas after the heater's needs had been met would be burnt and vented to atmosphere. It was only due to the geographical coincidence of having sewage works and gasworks together that had made it economically possible for the surplus sewage gas to be taken into the gasworks.

The gas left the holder via a mechanically-operated control valve that was actuated by the holder. When the holder was full the valve was open and when the holder was two-thirds full it closed. A 4-in. main took it into the gasworks where it entered the crude gas stream just previous to the condensers.

A gas with such a high carbon dioxide content was very difficult to burn with a normal type of burner and before the Boys calorimeter could be used a specially designed burner had to be obtained. Regular testing of this intake gas using this modified Boys calorimeter had given an average figure of 626 B.t.u. per cu.ft.

The specific gravity of this gas was quite high, and from a number of determinations, using a Bell-type gravitometer, the average specific gravity was 0.86. From these two average figures the Wobbe Index was 675, whereas the coal gas figure, taking 450 B.t.u. per cu.ft. for the quality and .53 as the specific gravity, was 618.

Mr. Townsend concluded that since commencing to take this sewage gas they had received 1,283,000 cu.ft. up until November 30, this representing only 2.09% of the coal gas made in the same period. Such a small percentage had no effect on the town gas characteristics.

Various questions were raised during the discussion by Mr. J. C. Macdonald, Perth; Mr. J. T. Christie, Dundee; and Mr. D. Elgin, Edinburgh. Mr. Townsend told Mr. Christie that sewage gas had very little odour, and agreed with Mr. Elgin that the importance of the subject was growing in view of the effects—only now beginning to be felt—of the 1951 River Pollution Act.

'Service Renewals by Extraction' was the title of a paper by Mr. Ian C. Kidd, Falkirk, who described trials with a hydraulic pipe extractor in the Grangemouth area. It was apparent, he said, that from a cost viewpoint, renewals carried out by the hydraulic pipe extractor were a great deal cheaper than if they were done by traditional methods. It was also pretty clear that the greater the length of service under a metalled surface the greater would be the savings.

But there were several features of this new method of service renewals which could be improved upon. To avoid the caving in of the end wall of the trench under pressure, it had been found useful if a steel plate of ¼-in. thickness and of an area approximately that of the trench end wall was placed behind the extractor, thus spreading the pressure over a much greater area.

Some method of shearing the short section of the pipe extracted by ram seemed a necessity as it was a decided disadvantage when this portion must be cut by either pipe cutters or hacksaw. When the rods were in use it was extremely difficult to cut off the extracted pipe without interfering with the rods. It would seem feasible that some more flexible medium could be employed.

Concerned

A feature about which he had been concerned was the fact that whenever extraction commenced the consumer was left without gas. Providing all went well this need not be a great handicap, but if trouble was encountered, consumer relationship might be affected.

He was of the opinion that service renewals using the hydraulic pipe extractor were a worthwhile proposition, providing that each job was suitable for this method and was properly planned to avoid any undue interruption in the gas supply.

Mr. A. M. Johnston, Dundee, thought the use of the machine might be rather limited, particularly in cities, and asked what proportion of service renewals could be carried out by this method. Mr. Kidd did not agree that the method was not applicable in cities. He had found not a very high proportion of service renewals to be suitable—perhaps 25 to 30% might be a rough figure.

Mr. R. E. Chandler, Service and Sales Manager, Dundee Group, introduced a paper on 'The New Domestic/Commercial Market,' with the comment: 'We in Scotland are still smarting under the unfair criticism and Press comments on the Board's method of increasing the price of gas, which, although similar in method to local fuel competitors and indeed to the local Town Council's system, received publicity from the local and national press alike that did not help our relationship with the general public. How deep is the damage wrought? Only time in perhaps the next 12 months will tell.'

He expressed the opinion that it was to the bulk domestic and commercial buyers that he thought they must turn their immediate attention, to help increase the use of gas. In this field he believed they had a wonderful opportunity with the application, to the average consumer, of the domestic hot water and selective warm air system, also the small-bore central heating system.

SE-DUCT IN NEW SCOTTISH FLATS

THE first Scottish municipal flats to be equipped with SE-duct heating are nearing completion at South Nitshill, Glasgow.

In 1957, members of the Glasgow Corporation housing and works department were invited to visit the Old Kent Road works of the South Eastern Gas Board. There they were so impressed with a prototype that they adopted it in principle for installation in a future block of municipal flats.

On January 8, Mr. Robert Bruce, New Buildings Gas Sales Officer, Glasgow and Western Division of the Scottish Gas Board, took 32 members of the West of Scotland Junior Gas Association over the new flats, later reading a paper to them entitled 'Gas Heating and Hot Water Services for New Homes.'

WORLD'S LARGEST OIL-GAS PLANT

British firm wins the contract

HUMPHREYS & GLASGOW LTD., in association with their Japanese licensees, have won an order to install an oil-gasification plant in Osaka, which will eventually be the largest of its kind in the world.

By the end of this year four units each making 5 mill. cu.ft. of town gas a day will be in operation. The total cost of this installation will be about £700,000. Eventually further units will be added to bring the total capacity of the plant to 30 mill. cu.ft. a day.

Onia-Gegi process

The plant, ordered by the Osaka Gas Co. Ltd. for its new Hokko works, employs Humphreys & Glasgow's Onia-Gegi process, which enables town gas to be produced from a wide range of hydrocarbons, including heavy fuel oil.

Special equipment exported from Britain will include catalysts, hydraulic automatic control equipment and oil burners. Close collaboration with the Japanese companies Ishii Iron Works and Okura Trading Company will be maintained during the constructional and engineering stages. The rest of the plant will be manufactured by Ishii Iron Works to Humphreys & Glasgow's designs. The commissioning will be under the supervision of a Humphreys & Glasgow engineer.

The new plant will be the third Onia-Gegi installation in Japan. Two smaller units, each producing 500,000 cu.ft. of gas a day, were recently commissioned at Yaizu and Himeji and are now operating.

The Osaka Gas Company is the second largest in Japan and supplies three major cities, Osaka, Kobe and Kyoto, with a combined population of 5½ mill. The area is supplied with gas by a high-pressure distribution network, fed from five large gas-producing stations.

Long-service awards

SIXTY-ONE Scottish Gas Board employees were presented with watches, cameras, clocks or silver condiment sets to mark 25 years service or more, at a function in Hamilton. The party, from Airdrie, Biggar, Coatbridge, Hamilton, Lanark, Motherwell, Strathaven and Uddingston, were entertained at tea by a quartet from the Scottish Gas Board Band.

At a ceremony in Perth, 14 members of the Board's Central Division staff from Sterling and district received long service awards. The presentations were made by Mr. W. Nicol Baird, Divisional General Manager.

Minister at North Eastern H.Q.

Arriving at Board headquarters, left to right: Mr. G. E. Currier, Deputy Chairman; Dr. R. S. Edwards, Chairman, and the Minister.

DURING his recent three-day fact-finding visit to Yorkshire the Minister of Power, Mr. Richard Wood, met the Chairman, members and the chief officials of the North Eastern Gas Board. He was shown the modern centralised accounting system, in which two electronic computers are used, housed in a new extension at Board headquarters.

The decision to extend the use of the punched card system and ally this with electronic computers was taken in 1955, and the final stages of the changeover are now being reached. By June, 1960, control of 350,000 quarterly credit gas accounts will be centralised along with cash and other customer accounting records, control of hire-purchase, products and other chargeable accounts.

It was anticipated that when work was finally completed, a saving in costs in the region of £75,000 a year would be possible. It is now known that this saving will be achieved and possibly exceeded.

CONTROVERSIAL GASWORKS CLOSES: SOUTHERN AREA GRID TAKES OVER

OXFORD gasworks of the Southern Board will close down on March 31, Employees were told on January 11.

The closure of the works has been made possible by the completion of the area gas grid and the increased gas-making capacity of the Reading gasworks. Through the grid it would be possible to supply Oxford with gas from as far as Southampton or Poole, but under normal circumstances the supply will come from Reading.

Human problems

The Board state that they have appreciated that their plans for modernisation involve considerable human problems, especially when redundancy results. The 105 employees at Oxford works will be given individual interviews with the management to discuss their future if they wish. Close liaison is maintained with the local office of the Ministry of Labour to assist in finding alternative employment when another job cannot be found within the Board, and everything possible will be done to avoid hardship. In some cases where qualifying length of service has been completed, the Board will consider claims for compensation.

Site purchased

Oxford has been receiving regular supplies of gas from Reading since April 1, 1952. Gas making ceased at Oxford's former North Bank gasworks on March 31, 1954. The plant was maintained in workable condition until demolitions began, and early in 1958 the site was purchased by the Corporation.

In due course the Board will be disposing of unwanted parts of their property on the South Bank. Both sites feature prominently in local development plans. The works has long been criticised for its alleged atmospheric pollution and its effect on the city's appearance.

PERSONAL NOTES

MR. W. H. SMITH, Chairman of Allied Ironfounders, has decided to retire from the Board on March 31. He has spent more than 60 years in the industry and was one of the original directors when the present holding company was formed in 1929. The new chairman will be MR. G. S. STEVEN, who is Vice-Chairman and Joint Managing Director and who will continue as Joint Managing Director with MR. H. C. WILSON BENNETTS. Mr. Steven, who is 53, has been connected with the Allied group since 1925, when he joined McDowall Steven & Company, of Falkirk. He later served at various of the group's centres in both Scotland and England.

MR. A. W. EVANS, formerly sales manager of Air Control Installations, has been appointed Manager of Ambuco Ltd. Ambuco will specialise in custom engineering industrial dust recovery systems and is the recently-formed subsidiary of Buell Engineering Co. Inc. of New York which is itself a wholly owned subsidiary of Consolidated Gold Fields of South Africa Ltd. Mr. Evans will be spending the next two months in America studying methods and current developments and during this time will be accompanied by his chief assistant, MR. W. F. MORRISON. In the meantime, MR. JOHN HERBST of the New York office will be acting as Manager in London.

MR. W. LIONEL FRASER, Chairman of Babcock & Wilcox, Ltd., is to retire from the Board after the company's annual meeting on May 26 next. SIR KENNETH HAGUE, now Deputy Chairman, will take over the chairmanship, and SIR REGINALD VERDON SMITH will become deputy chairman. In acknowledgment of his services, the Board has unanimously decided to submit a resolution to the next annual meeting for the creation of the position of president of the company. If approved, the directors propose to invite Mr. Fraser to accept the appointment, thereby maintaining his association with the company.

MR. J. G. ABBOTT, who ensured Windsor homes were supplied with gas for cooking and heating during the second world war and the severe floods of 1946-1947, has retired from the North Thames Gas Board. Mr. Abbott was manager of the Windsor and Ascot district and formerly engineer and manager of the Windsor Gas Light Company.

MR. A. NADIN has been appointed General Manager of Brayshaw Furnaces Ltd., and Brayshaw Tools Ltd., Belle Vue Works, Manchester, 12. Prior to his appointment as works manager with the Brayshaw companies in 1957, he was connected with Samuel Osborn & Co. Ltd., Sheffield, and their subsidiary companies.

"The Gas Council place on record the gratitude of its members for the unique services rendered to the gas industry by Sir Harold Smith during the past 53 years culminating, after three years as Deputy Chairman, in eight years as Chairman of the Council; their admiration for the ability and energy with which he has led the industry during a period in which far-reaching developments have been initiated; and their warmest good wishes for his future health and happiness after his retirement on December 31, 1959."

The illuminated address, embossed on vellum, presented to Sir Harold recently.

MR. NORMAN RIDING, a figure well-known to visitors to the Institution of Gas Engineers headquarters in London, retired last week. Mr. Riding acted as caretaker, hall-porter and commissionaire. He saw considerable service in the 1914-18 war as a sergeant-pilot in the old Royal Flying Corps. During the last war, he served as a warrant-officer in the Royal Air Force. He joined the Institution ten years ago, before which he was a temporary employee of the Ministry of Labour. A married man, Mr. Riding has bought a caravan and has made his home in Rochester, Kent. He previously lived on the premises of the Institution.

MR. J. E. C. BAILEY, C.B.E., Chairman and Managing Director of Baird & Tatlock (London) Ltd. and Hopkin & Williams Ltd., will leave the U.K. by air on January 30 to visit the companies' branches, agents, representatives and customers throughout East, Central and South Africa. The tour will include visits to Nairobi, Ndola, Salisbury, Bulawayo, Johannesburg and Durban, and will help to promote the export of scientific instruments and laboratory apparatus and reagents to these areas.

MR. P. C. EGAN has been appointed Assistant Engineer at the Kensal Green works of the North Thames Gas Board.

OBITUARY

MR. WILLIAM HENRY BENNETT died in Brighton on January 16 as the result of an accident. He was in his 78th year. Identified with Redhill and Reigate, the East Surrey Gas Company, the Southern Association, the founding of Amalgamated Gas and Water undertakings, he was an outstanding personality of the pre-nationalised gas industry and held in the highest esteem by a very wide circle of friends.

CORRESPONDENCE

Juniors' membership

DEAR SIR,

The President of the I.G.E. advocates, as reported in your January 13 issue that membership of the junior gas associations should be made easier.

I would go further, and suggest that the district sections of the Institution should be merged with the junior gas associations, and academic requirements for membership abolished. The Institution is the only organisation corporate membership of which qualifies one for the title of Chartered Gas Engineer. That being so, why restrict membership of the other associations? Admit anyone who is sufficiently interested in the gas industry to pay his subscription and give up time to attend meetings.

There are not enough first-class papers and visits to keep so many associations going. The 'nursery' function of the juniors can be maintained by short paper evenings, but it would not be necessary to scrape the barrel to fill the programmes.

'THERMION.'

January 15, 1960.

COMING EVENTS

January 23.—WESTERN JUNIORS: Bridgwater Works. Tour of works, followed by a paper on 'The Use of Primary Flash Distillate in Continuous Vertical Retorts,' by P. Trevelyan. 2 p.m.

January 25.—EASTERN G.C.C.: Connaught Rooms, Great Queen Street, London, W.C.2. 2 p.m.

January 25.—WEST MIDLANDS G.C.C.: Council House, Birmingham. Council meeting at 2.30 p.m.

January 26.—THE INSTITUTION OF PLANT ENGINEERS, SOUTH WALES SECTION: South Wales Engineers' Institute, Park Place, Cardiff. 'Safety in Uses of Industrial Gases and Equipment,' by M. T. Reeks, Safety Investigating Officer, British Oxygen Gases Ltd. 7.30 p.m.

January 26.—THE SOCIETY OF INSTRUMENT TECHNOLOGY: Mansion House, 26, Portland Place, London, W.1. Symposium on flame failure detection. 7 p.m.

January 27.—SOUTHERN G.C.C.: Conference Room, Civic Centre, Southampton. Council meeting at 11 a.m.

January 27.—EASTERN JUNIORS: Visit to Blackstones Engineering Works, Stamford. Paper on 'Application and Maintenance of Stationary Diesel Engines,' by C. C. Townsend.

January 29.—NORTH THAMES G.C.C.: Westminster City Hall. Council meeting at 2.30 p.m.